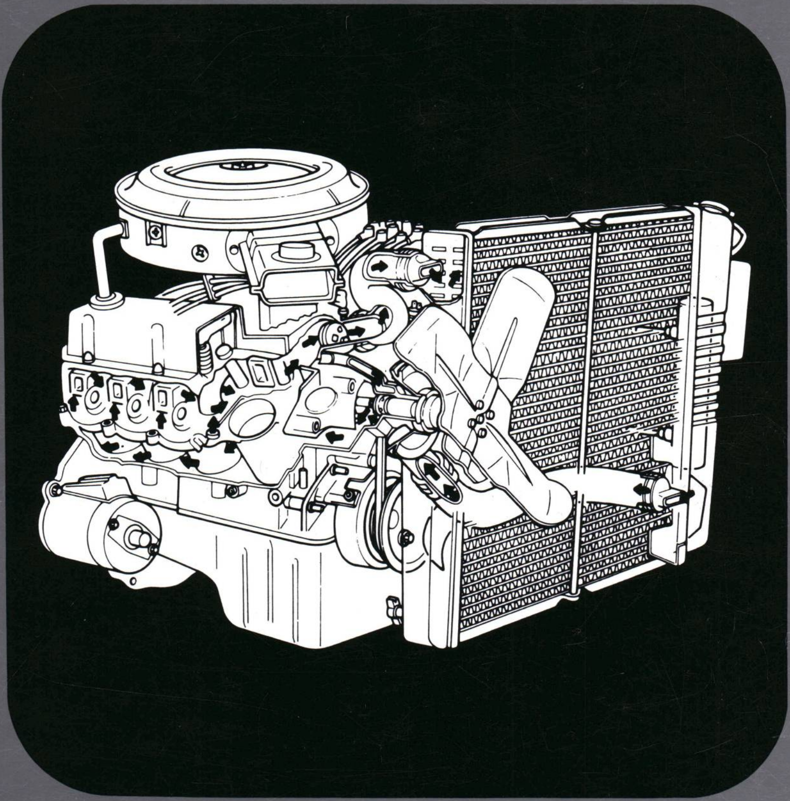
engine cooling systems and components



Supplement to Select STST Courses

IMPORTANT SAFETY NOTICE

Appropriate service methods and proper repair procedures are essential for the safe, reliable operation of all motor vehicles, as well as the personal safety of the individual doing the work. This manual provides general directions for accomplishing service and repair work with tested, effective techniques. Following them will help assure reliability.

There are numerous variations in procedures, techniques, tools, and parts for servicing vehicles, as well as in the skill of the individual doing the work. This manual cannot possibly anticipate all such variations and provide advice or cautions as to each. Accordingly, anyone who departs from instructions provided in this manual must first establish that he compromises neither his personal safety nor the vehicle integrity by his choice of methods, tools or parts.

As you read through the procedures, you will come across NOTES, CAUTIONS, AND WARNINGS. Each one is there for a specific purpose. NOTES give you added information that will help you to complete a particular procedure. CAUTIONS are given to prevent you from making an error that could damage the vehicle. WARNINGS remind you to be especially careful in those areas where carelessness can cause personal injury. The following list contains some general WARNINGS that you should follow when you work on a vehicle.

- Always wear safety glasses for eye protection.
- Use safety stands whenever a procedure requires you to be under the vehicle.
- Be sure that the ignition switch is always in the OFF position, unless otherwise required by the procedure.
- Set the parking brake when working on the vehicle. If you have an automatic transmission, set it in PARK unless instructed otherwise for a specific service operation. If you have a manual transmission, it should be in REVERSE (engine OFF) or NEUTRAL (engine ON) unless instructed otherwise for a specific service operation.
- Operate the engine only in a well-ventilated area to avoid the danger of carbon monoxide.
- Keep yourself and your clothing away from moving parts when the engine is running, especially the fan and belts.
- To prevent serious burns, avoid contact with hot metal parts such as the radiator, exhaust manifold, tail pipe, catalytic converter and muffler.
- Do not smoke while working on the vehicle.
- To avoid injury, always remove rings, watches, loose hanging jewelry, and loose clothing before beginning to work on a vehicle. Tie long hair securely behind your head.
- Keep hands and other objects clear of the radiator fan blades. Electric cooling fans can start to operate at any time by an increase in underhood temperatures, even though the ignition is in the OFF position. Therefore, care should be taken to ensure that the electric cooling fan is completely disconnected when working under the hood.

The recommendations and suggestions contained in this manual are made to assist the dealer in improving his dealership parts and/or service department operations. These recommendations and suggestions do not supersede or override the provisions of the Warranty and Policy Manual or the Shop Manual and in any cases where there may be a conflict, the provisions of the Warranty and Policy Manual or the Shop Manual shall govern.

The descriptions, testing procedures, and specifications in this handbook were in effect at the time the handbook was approved for printing. Ford Motor Company reserves the right to discontinue models at any time, or change specifications, design, or testing procedures without notice and without incurring obligation. Any reference to brand names in this manual is intended merely as an example of the types of tools, lubricants, materials, etc. recommended for use. Equivalents, if available, may be used. The right is reserved to make changes at any time without notice.

WARNING: Many brake linings contain asbestos fibers. When working on brake components, avoid breathing the dust. Breathing the asbestos dust can cause asbestosis and cancer.

Breathing asbestos dust is harmful to your health.

Dust and dirt present on car wheel brake and clutch assemblies may contain asbestos fibers that are hazardous to your health when made airborne by cleaning with compressed air or by dry brushing.

Wheel brake assemblies and clutch facings should be cleaned using a vacuum cleaner recommended for use with asbestos fibers. Dust and dirt should be disposed of in a manner that prevents dust exposure, such as sealed bags. The bag must be labelled per OSHA instructions and the trash hauler notified as to the contents of the bag.

If a vacuum bag suitable for asbestos is not available, cleaning should be done wet. If dust generation is still possible, technicians should wear government approved toxic dust purifying respirators.

OSHA requires areas where asbestos dust generation is possible to be isolated and posted with warning signs. Only technicians concerned with performing brake or clutch service should be present in the area.

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INTRODUCTION

In keeping with the objective of providing basic training, this manual provides general information about the cooling systems which are currently used in Ford Motor Company vehicles. The illustrations which have been selected show typical rather than specific conditions.

By tailoring the text and illustrations in this manner, it is hoped that thorough coverage of the subject will be provided and early obsolescence of information will be avoided. Finally, it is emphasized that the content of this manual, by being generalized, is not an official guide to use when working on a vehicle that is to be placed in actual service. It is essential that the appropriate shop manual, with its supporting Technical Service Bulletins, be consulted for the latest procedural data and service specifications.

DESCRIPTION AND OPERATION OF COOLING SYSTEM COMPONENTS

BASIC FUNCTIONS OF THE COOLING SYSTEM

Functionally, the cooling system in an automobile engine is not limited to a cooling process. It is more correct to describe it as a system which is designed not just to cool but to maintain engine operating temperatures within limits specified by the manufacturer. A range between a low of 193°F and a high of 221°F is typical. This range will vary slightly, however, between engines with differing displacement ratings.

The intense heat which is generated during the internal combustion process in an automobile engine must be controlled and dissipated continuously. Some of this heat is used up in the course of forcing the engine piston down through the cylinder bore during its power stroke. Some of it is forced out of the cylinder during the exhaust stroke. Concurrently, an approximate 1/3 balance of the heat generated by internal combustion is being transferred into the cooling system.

As the engine reaches the point where its operating temperature exceeds the temperature of the metal surfaces which enclose the cylinder bores in the block and the combustion chamber, manifolds, and spark plug seats in the head(s), the heat is transferred through the metal to the surrounding coolant. This coolant is being continuously circulated through cast-in passages in the block and head(s).

A thermostat monitors the coolant flow by responding to temperature changes. When the coolant is too hot, the thermostat will open and direct the coolant flow through the radiator; when the coolant is too cold, the thermostat will close and by-pass its direction of flow back into the block and head(s) where it will pick up additional heat.

Its course through the complete cooling system is illustrated in Figure 1.

The arrows trace the flow of coolant from (1) the radiator outlet hose, (2) through the water pump, (3) through the cast-in water jackets in the block

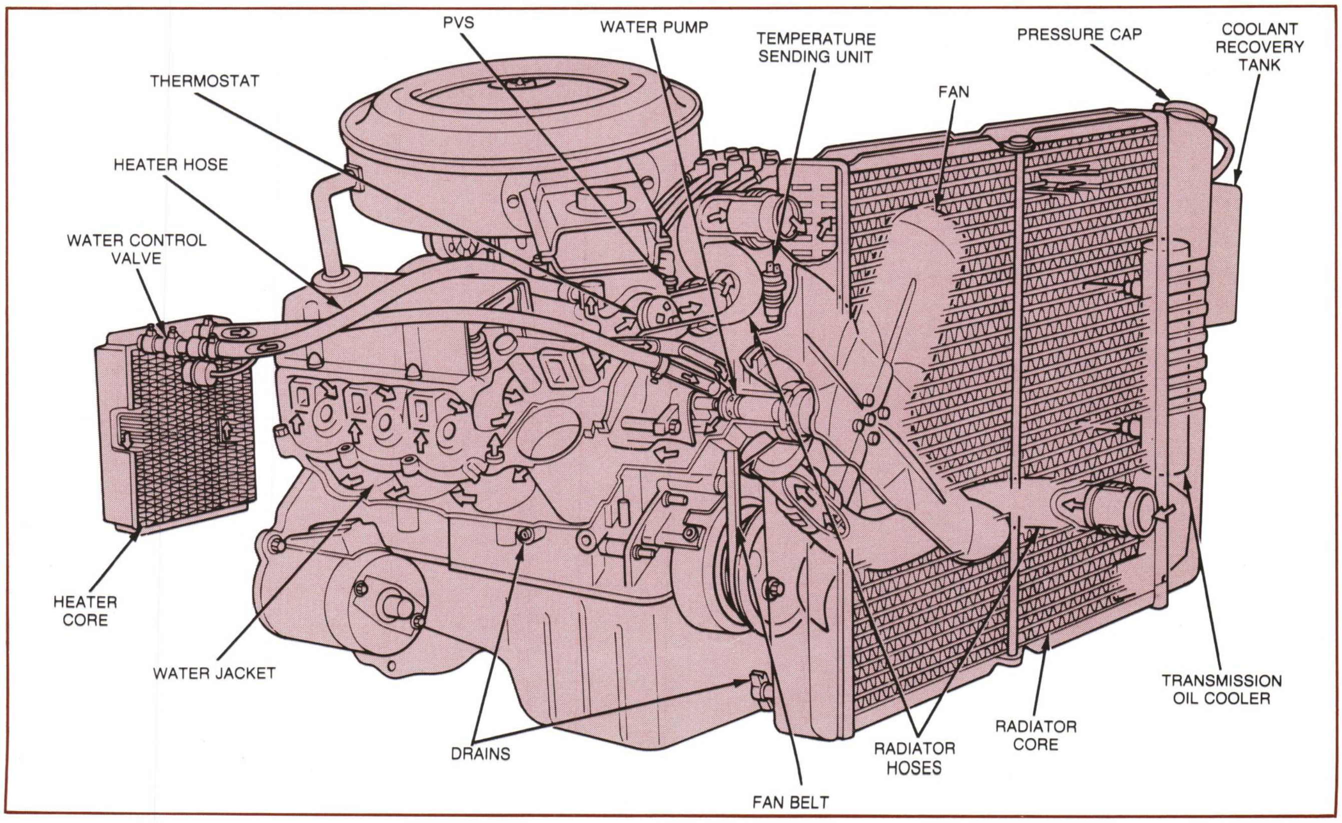


Figure 1. Coolant Flow Through the Cooling System

and head(s), (4) past the thermostat, (5) back into the radiator where the solution flows through the radiator core, and (6) completes the cycle as it once again enters the outlet hose. The water jackets to which reference is made in Item 3 of this sequence are chambers which have been formed in the cylinder block and cylinder head castings during manufacture. When the engine is made ready to operate, these jackets are filled through the radiator filler neck with engine coolant which circulates under pressure from the water pump.

The configuration of the water jackets in the block is such that coolant will circulate around each bore. There are also coolant passages cast into the machined upper edges of the cylinder block which mate with passages similarly cast into the lower machined edges of each cylinder head. As the pump forces coolant flow around the bores, it simultaneously forces it through these passages between the block and head(s). In the head, the jackets surround the spark plug seats, valve guide openings in the head casting, and the intake and exhaust manifold ports. If the engine has a V-block, the block and each head casting incorporate the crossover passages needed to ensure that coolant will be supplied to both the right and left banks of the cylinders and heads.

It is important to remember that the mating surfaces of the block and head(s) are sealed with a gasket which has cutouts that match the passage openings between these assemblies. If the gaskets are not properly installed, they could cover the coolant passages. The result would be severe overheating.

Each of the components mentioned in the preceding description of a cooling cycle, as well as some of the other components illustrated in Figure 1, are described in greater detail in the text which follows.

RADIATORS

Functions of the Radiator

By definition, the function of the radiator in an automobile is to provide a coolant filled container which will radiate the superfluous heat contained in the coolant into the open air in the engine compartment. As a result of this heat loss, the coolant pumped into the water jackets will be cooled to a point within temperature specifications and better prepared to absorb its approximate one-third share of the excess heat generated during combustion.

Keep in mind that the flow of coolant through the radiator is being controlled continuously by a thermostat as it responds to its narrow temperature range between opening and closing. In this way, engine coolant temperature is closely guarded against becoming either too hot or too cold.

The rate at which engine heat is removed by the cooling system depends upon several conditions: (1) radiator size, (2) water pump capacity, (3) temperature of the outside air, (4) speed at which air (ram or fan-drawn) is flowing through the radiator, (5) thermostat opening temperature, and (6) engine load.

If the cooling system fails to perform its job of maintaining the proper temperature, engine service life may be significantly shortened. If the engine is allowed to run when it is **too hot**, it may cause detonation, burned valves, scored pistons, and damaged bearings. In addition, the excessive heat may alter the viscosity of the lubricating oil to the point where its detergent action is nullified, and varnish begins to form on metal parts. If the engine is allowed to run when it is **too cold**, several damaging conditions may result:

- Cylinder wall wear could increase significantly.
- Engine sealing provision could break down.
- Fuel vaporization will be incomplete. This may lead to a loss in fuel efficiency, an increase in emission pollutants, and dilution of the engine oil because water and gasoline are accumulating in the crankcase.

There are two basic designs of radiators currently in use in Ford Motor Company vehicles. The first is a crossflow design which may be further categorized into one of two types depending upon its component material. One has a copper/brass construction; the other has an aluminum core. Both of these crossflow types have a side-mounted inlet and outlet tank. The second design is a downflow radiator. It was used extensively in passenger cars during recent model years but is now confined primarily to truck applications.

Descriptions and illustrations of each of these designs follow. They begin with the older downflow design and then proceed to coverage of the more recent crossflow design.

Downflow Radiator

The downflow radiator has an upper and lower coolant tank as shown in Figure 2.

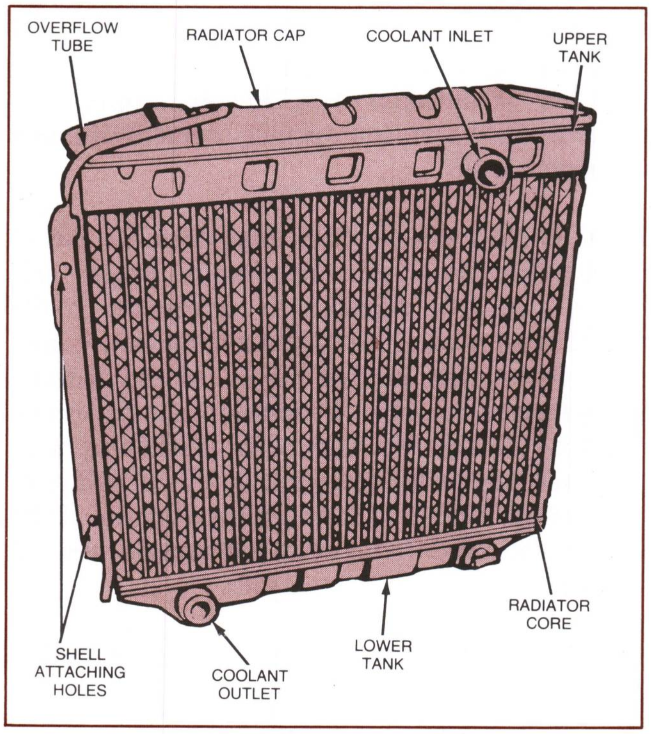


Figure 2. Downflow Radiator

Functionally, coolant returning from the engine circulates into the top tank under system pressure and flows downward through the radiator tubes into the bottom tank. During this downflow segment of the coolant flow cycle, ram air and/or air drawn in by the engine cooling fan is flowing past the network of cooling fins which surround the full length of the exposed surface of each tube. The liquid, thus cooled, is continuously displacing the liquid which preceded it into the bottom tank. From the bottom tank, the coolant is directed through the lower radiator hose to the water pump. From there, it continues its cycle through the engine and then returns to the radiator through the inlet hose attached to the upper tank.

Notice in Figure 2 that an overflow tube is provided to vent coolant from the system when temperatures and pressures exceed specified system limits.

Crossflow Radiators

Instead of top and bottom tanks, crossflow radiators have a pair of side tanks; one is an inlet tank and the other an outlet tank. The inlet tank receives the pressurized flow of hot coolant from the engine. From there it courses through the tubes in the radiator core from the inlet to the outlet tank. Again, the fins in the core direct air around the core tubes to lower the coolant temperature.

At this point, the text has meant to establish two things: (1) that coolant flow may be from the top to the bottom of a radiator assembly, or (2) the flow may course horizontally from one side to the opposite side of a radiator core. These are major design differences, but the function of each design is the same . . . to maintain the temperature of engine coolant within desirable limits.

Body designers, in their continuing efforts to obtain as much aerodynamic advantage as possible, have pressed for low front end configurations. To help them achieve this objective, chassis designers have turned to the crossflow radiator which is lower and usually wider than its downflow predecessor.

As indicated in an earlier paragraph, there are two types of crossflow radiators: (1) the copper/brass and (2) the aluminum. The text will now concentrate on descriptions and illustrations of each.

DESCRIPTION AND OPERATION OF COOLING SYSTEM COMPONENTS

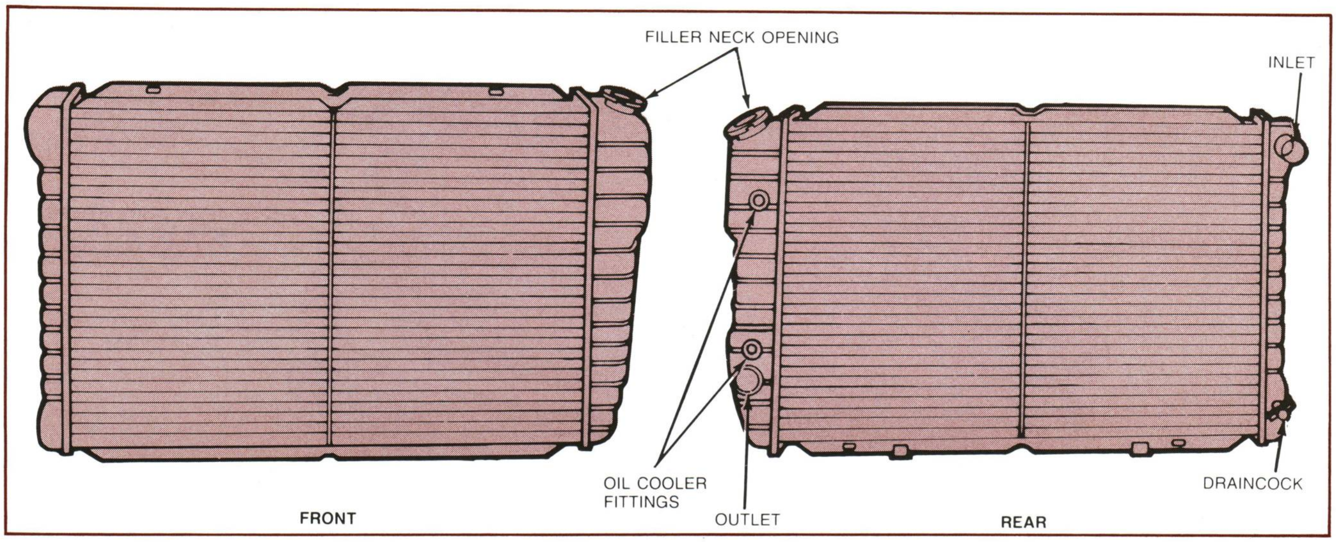


Figure 3. Copper/Brass Crossflow Radiator

Copper/Brass Crossflow Radiators

Figure 3 provides a front and rear view of a copper/brass radiator.

The preceding description of crossflow radiator operation applies to this design of radiator just as it does to a radiator with an aluminum core. There is a difference, however, in the serviceability of the two designs.

The copper/brass radiator, because of its component materials and the extensive use of solder during its manufacture, must either be serviced in the dealership by replacing the complete assembly, or it must be sent to a specialty shop for component service such as replacement of the draincock or the transmission oil cooler.

It is a Ford Motor Company recommendation that a fractured tank be replaced. There is a natural flexing action which accompanies the increases and decreases in pressure as the coolant temperature in the closed circuit rises and falls. This flexing action has been found to be sufficient to reinstate the leaking condition that the repair was intended to stop.

Aluminum Core Crossflow Radiators

Radiators with an aluminum core may either be assembled mechanically or the core may be vacuum brazed into the assembly. The mechanically assembled unit has round tubes in the core; the vacuum brazed unit has nearly flat tubes with elliptically shaped ends in its core. On both units, during manufacture, an epoxy is applied to the air side of the tanks. Figure 4 provides a disassembled view of an aluminum radiator. The illustration shows the installation with and without air conditioning.

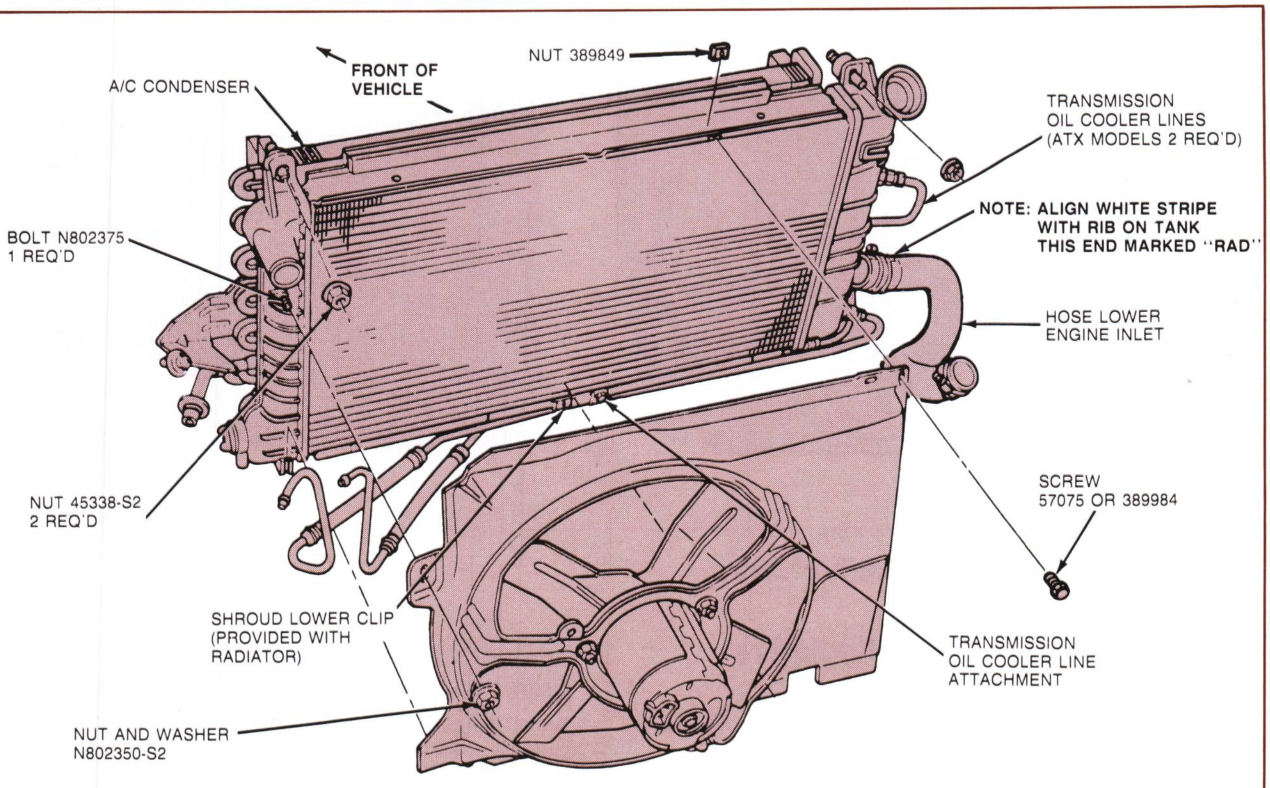
Draining the Radiator

Figure 5 shows the type of draincock installation used in an aluminum radiator. View A aligns a disassembled draincock with its installation point near the lower edge of the radiator inlet tank. View B shows the draincock fully assembled and ready for installation into the elbow-shaped neck in the inlet tank.

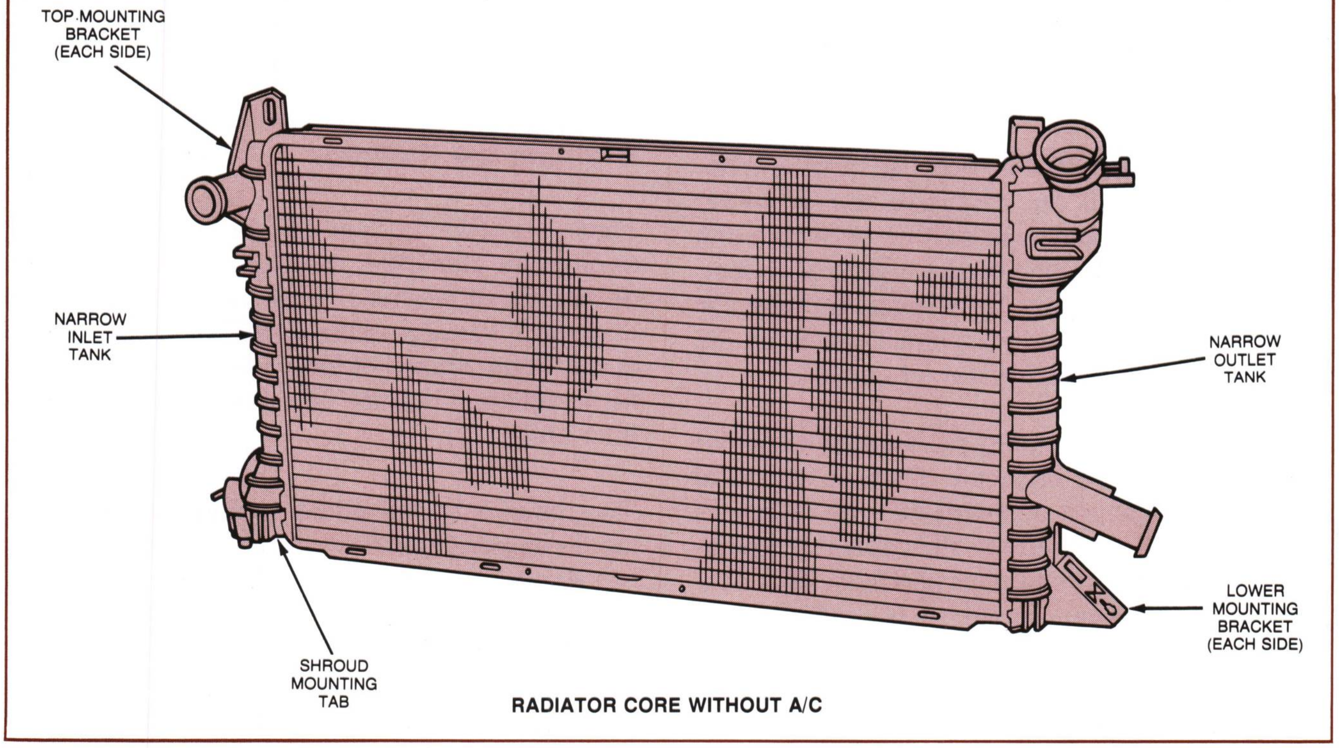
The radiator is drained by turning the draincock stem counterclockwise until coolant flows freely out through the draincock opening.

Coolant Drain Plugs

Opening the radiator draincock to release coolant from the radiator will not completely drain the system. That portion of the coolant supply still in the water jackets will remain unless the coolant


FRONT OF VEHICLE
NUT 389849
A/C CONDENSER
TRANSMISSION OIL COOLER LINES (ATX MODELS 2 REQ'D)
NOTE: ALIGN WHITE STRIPE WITH RIB ON TANK THIS END MARKED "RAD"
BOLT N802375 1 REQ'D
HOSE LOWER ENGINE INLET
NUT 45338-S2 2 REQ'D
SCREW 57075 OR 389984
SHROUD LOWER CLIP (PROVIDED WITH RADIATOR)
TRANSMISSION OIL COOLER LINE ATTACHMENT
NUT AND WASHER N802350-S2

RADIATOR INSTALLATION — WITH A/C


TOP MOUNTING BRACKET (EACH SIDE)
NARROW INLET TANK
NARROW OUTLET TANK
LOWER MOUNTING BRACKET (EACH SIDE)
SHROUD MOUNTING TAB

RADIATOR CORE WITHOUT A/C

Figure 4. Aluminum Core Radiator Installations

DESCRIPTION AND OPERATION OF COOLING SYSTEM COMPONENTS

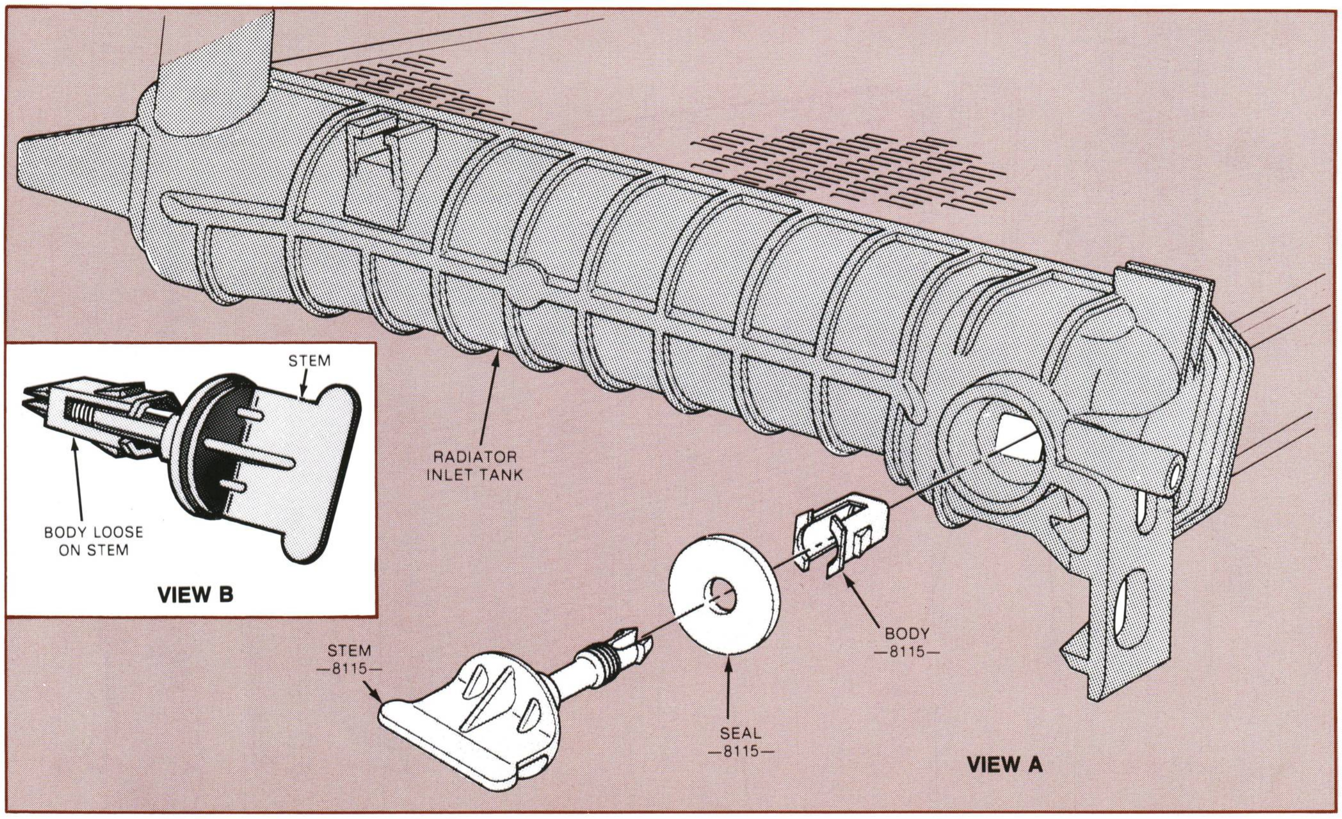


Figure 5. Draincock Assembly

drain plugs in the cylinder block are removed. Figure 6 illustrates a typical location for these plugs.

Transmission Oil Cooler

The fluid in an automatic transmission requires cooling. To fill this need, a cylindrical cooling tank is installed inside the radiator outlet tank. An input

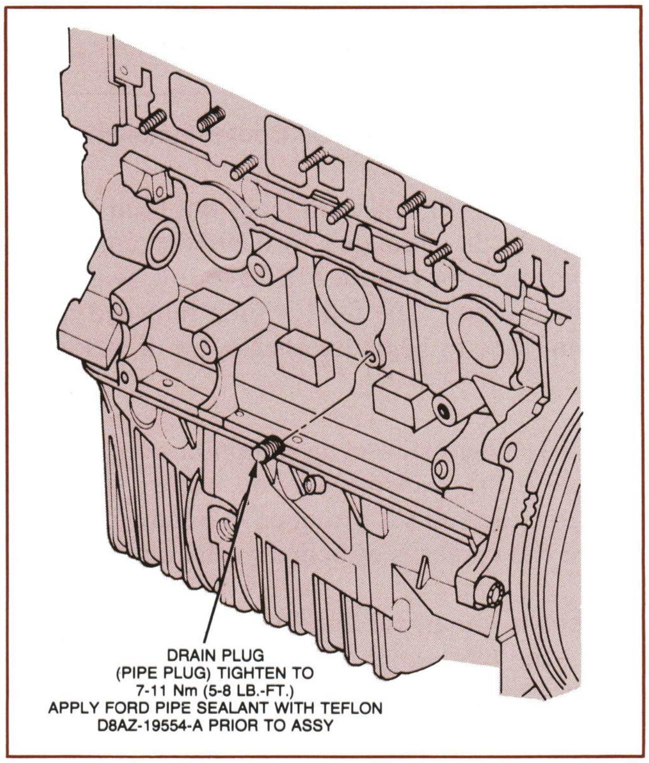

DRAIN PLUG
(PIPE PLUG) TIGHTEN TO
7-11 Nm (5-8 LB.-FT.)
APPLY FORD PIPE SEALANT WITH TEFLON
D8AZ-19554-A PRIOR TO ASSY

Figure 6. Coolant Drain Plugs in the Cylinder Block

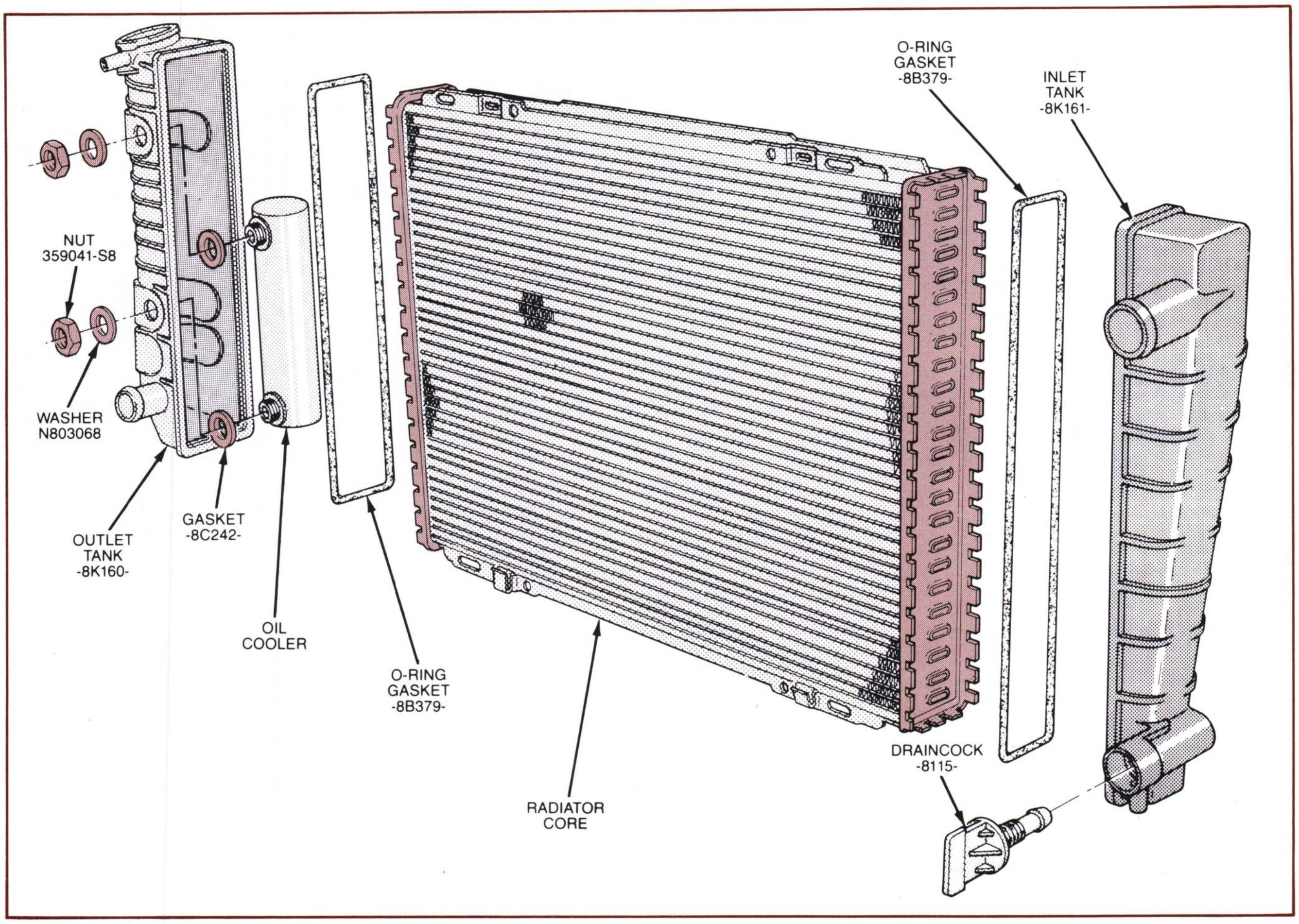


Figure 7. Transmission Oil Cooler Installation

line from the transmission feeds hot fluid into the cooler. As it circulates through the cooler, its temperature is reduced to a point within its specified limits. The fluid is then returned to the transmission to begin another cycle of absorbing heat.

A disassembled view of an aluminum core radiator including the transmission oil cooler tank and radiator side tanks is provided in Figure 7 to show where the cooler is attached to the outlet tank.

As shown, the upper and lower threaded attachments for the cooler have a washer-like gasket which seals the area between the cooler mounts and the holes through which they pass in the outlet tank. **Figure 8 shows the transmission oil cooler lines** which carry the flow of fluid into and out of the cooler.

Radiator Inlet and Outlet Tanks

Each crossflow radiator has an inlet tank mounted along one side of the radiator core and an outlet tank along the opposite side of the core. Figure 9 provides a disassembled view of one type of radiator currently being used.

There are two widths of side tanks and headers. They are used with the vacuum brazed core which has the flatter tubes. Figure 10 illustrates both the wide and the narrow tanks.

Each of the four tanks shown in Figure 10 is a moulded construction made from a glass-filled nylon material. An integral part of the tanks being shown are the fan shroud and radiator mounting brackets. The tanks themselves attach to the radiator core with bend-over tabs which are an integral part of the core assembly. An O-ring seats in a groove that encircles each end of the core to completely seal the joint between the core and its two side tanks.

The side tanks in a copper/brass radiator assembly are soldered onto the core. To remove either of these tanks, it is necessary to melt the solder joint between the tank and the core. This is an operation that requires a specialist's skill to control heat concentration and avoid unintentional solder melting and burn-through.

Radiator Cap

All Ford cooling systems are pressurized, and it is the function of the radiator cap to maintain this pressure within specified limits. The reason why system pressurization has been adopted on an industry-wide basis is the need to keep the boiling point of the coolant solution high enough so that vaporization will be avoided.

Under one atmosphere of pressure (14.69 psi), undiluted permanent anti-freeze will boil at 354.6°F (197°C). Water, under the same pressure, will boil at 212°F (100°C). The recommended 50/50 solution of water and permanent anti-freeze will boil at approximately 226°F (108°C).

Figure 11 illustrates one type of radiator cap used in a crossflow system. The cap shown is rated at 16 psi and has a tolerance of plus or minus 3 psi. This means that at its low end (13 psi), the cap must at

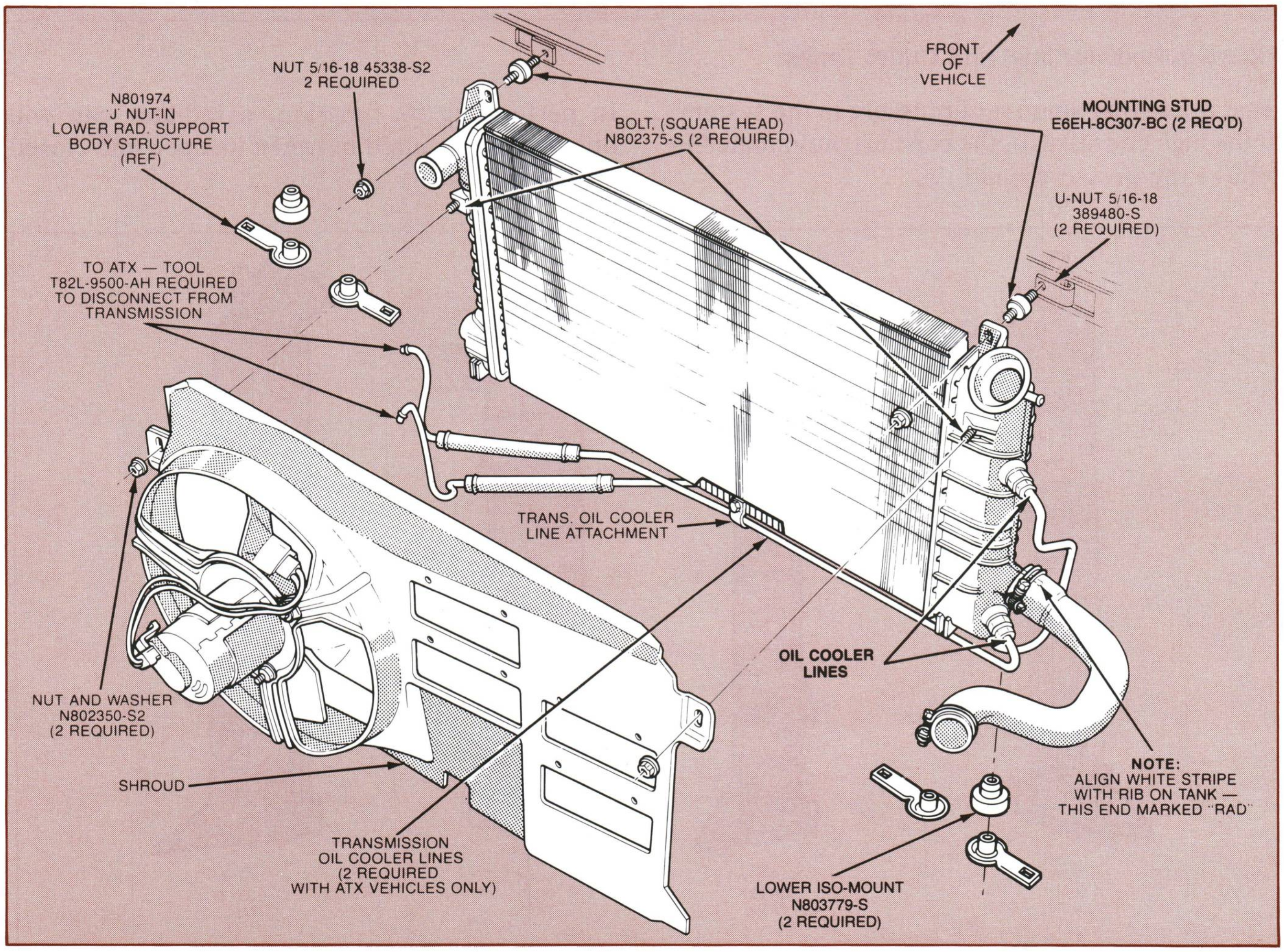


Figure 8. Transmission Oil Cooler Line Installation

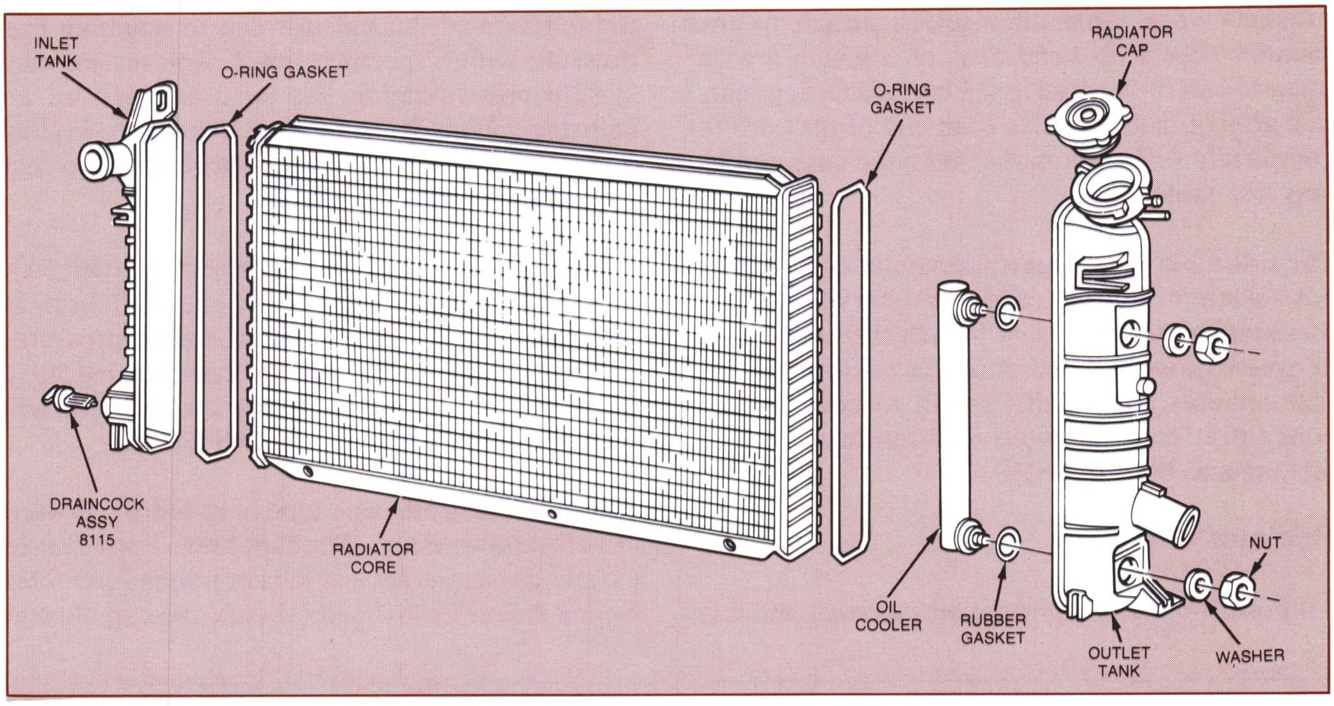


Figure 9. Radiator Inlet and Outlet Tanks

least retain that amount of pressure in the system; at the high end (19 psi), the cap must automatically relieve the pressure build-up.

In performing its function, a radiator cap will fluctuate as required between its open and closed positions.

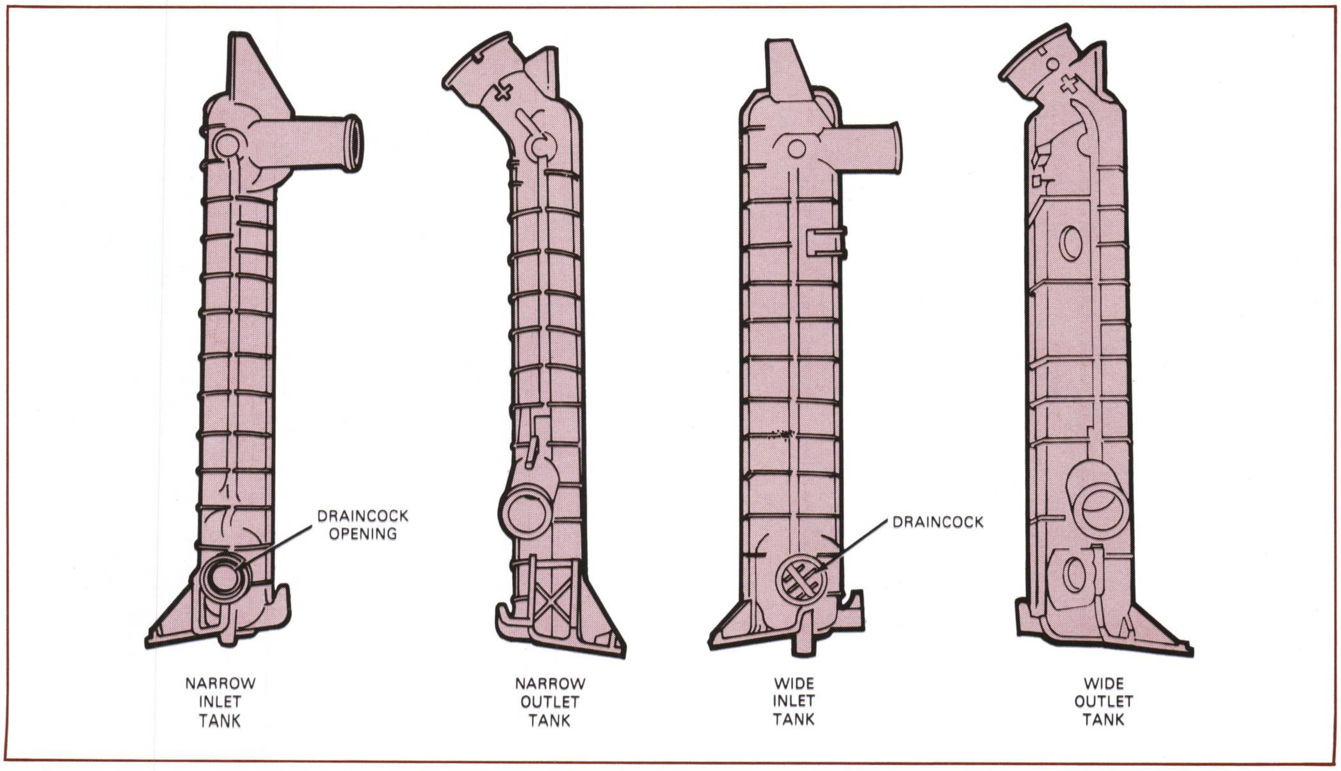


Figure 10. Wide and Narrow Tank Sets

DESCRIPTION AND OPERATION OF COOLING SYSTEM COMPONENTS

Cooling systems will vary in their requirements for a radiator cap. It is essential, therefore, for the appropriate shop manual to confirm the required pressure; and then, the pressure rating stamped on the cap should also be checked to be certain that it matches the specification.

A typical pressure cap has a large secondary metal and rubber seal positioned directly under the upper surface of the cap. Another primary rubber seal at the lower end of the cap assembly seats on a sealing surface inside the filler neck. A coil spring which is installed between these two seals around the vertical centerline of the assembly retains the seals in tight contact with their mating surfaces.

A pressure relief valve in the cap assembly responds to system pressure. When the maximum specified pressure is exceeded, the valve raises the seal off its seat in the filler neck. This action allows coolant to flow into the filler neck and out through a hose attached to the filler neck and into the coolant recovery reservoir.

Coolant Recovery Reservoir

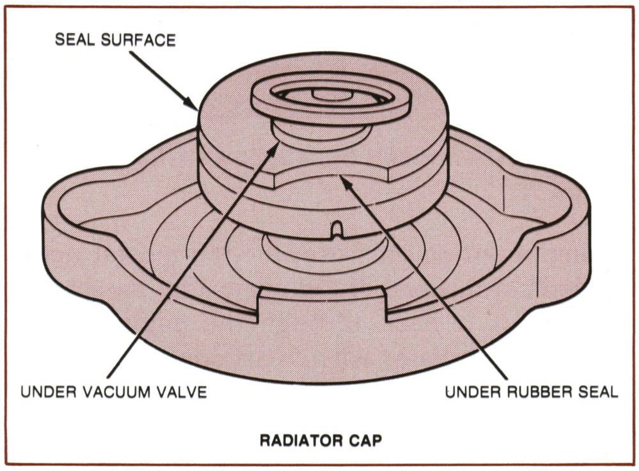
Figure 12 illustrates two of several coolant recovery system designs used in Ford Motor Company vehicles.

The complete coolant recovery system begins with the radiator cap. When the primary seal in the cap is raised off its seat, coolant flows into the filler neck and out through a plastic hose to a plastic reservoir. When coolant temperature decreases sufficiently, the primary seal re-seats and the vacuum valve in the radiator cap draws the coolant which escaped into the reservoir back into the radiator.

Functionally, the reservoir minimizes the problem of coolant loss which occurred when system pressure build-up was relieved through an open drain hose. In addition, the current reservoir designs provide a limited reserve of coolant and a container into which air bubbles in the system can be vented.

Thermostat

The thermostat is the cooling system component which maintains continuous coolant temperature control. As operating conditions change, coolant temperatures will increase or decrease. In response to these changes, the thermostat will fluctuate, as required, between its open and closed positions. While closed, it recirculates the coolant through the cylinder block and head(s) where it absorbs a share of the heat generated during the combustion process. When it is open, it will direct



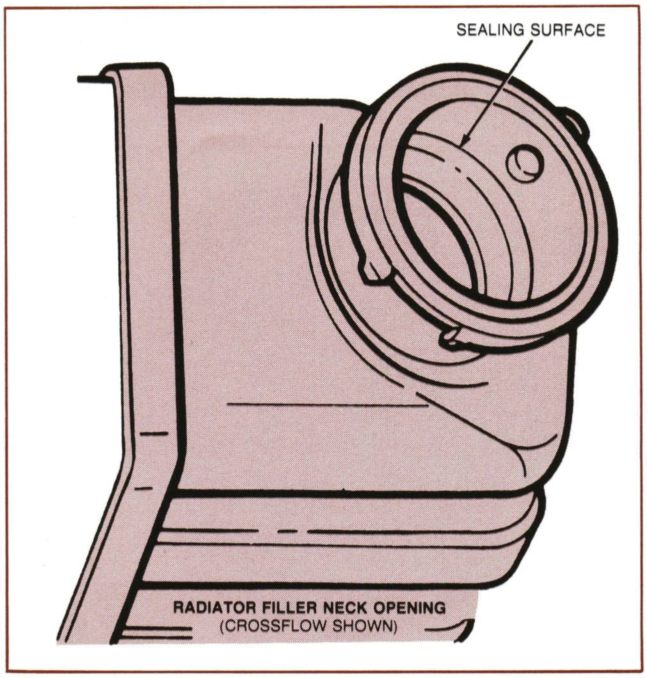


Figure 11. Typical Radiator Cap and Filler Neck Opening - Crossflow Radiator

DESCRIPTION AND OPERATION OF COOLING SYSTEM COMPONENTS

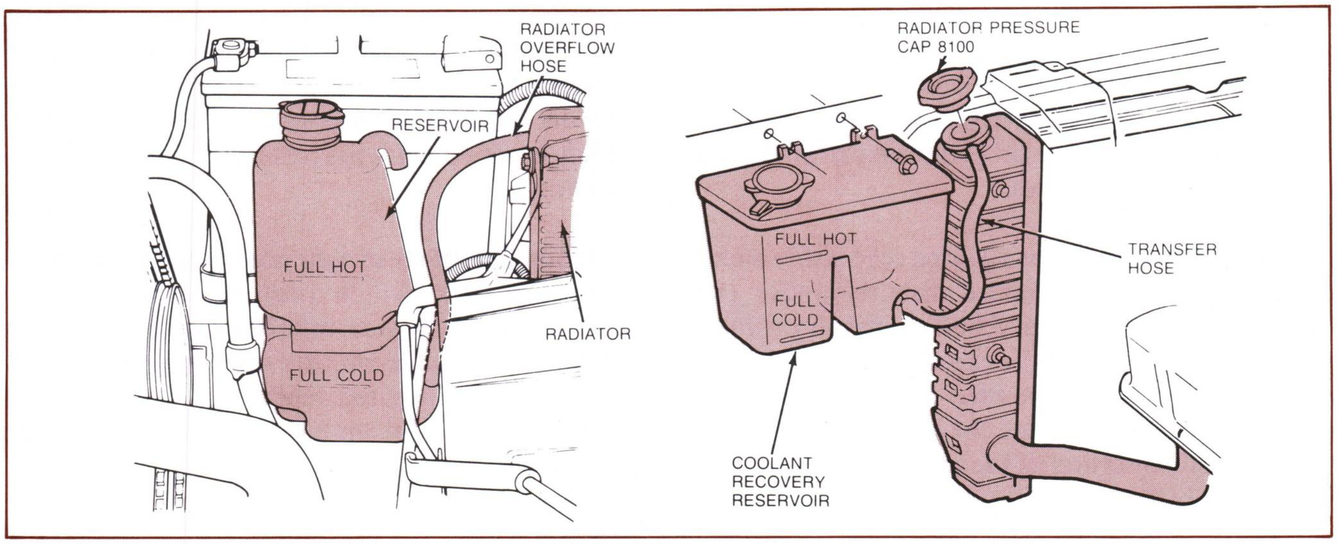


Figure 12. Coolant Recovery Systems

the coolant into the radiator where ram air or airflow drawn through the radiator by the engine cooling fan will decrease the coolant temperature.

Figure 13 illustrates a thermostat which contains a wax pellet and a coil spring which interact as coolant temperatures change. With this type of thermostat, the circulation of engine coolant to the radiator is blocked whenever the temperature of the coolant in the engine is below the minimum required to open the thermostat. When, however, engine coolant temperature is high enough to cause pellet expansion and a simultaneous overcoming of spring pressure, the thermostat opens and coolant, instead of following a by-pass which recirculates it back through the engine, flows through the radiator where it is cooled.

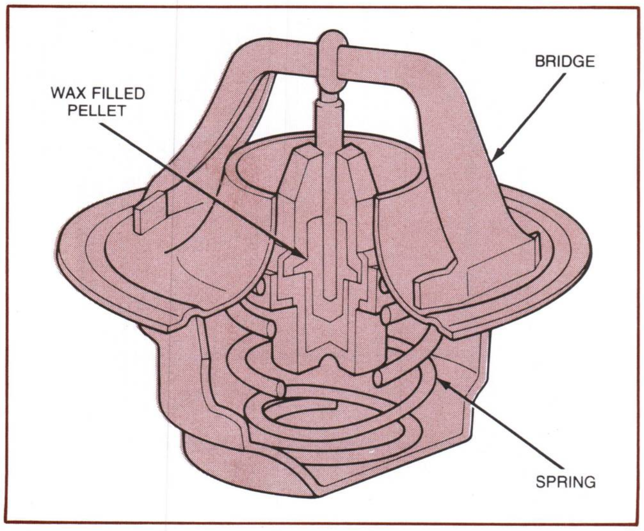


Figure 13. Thermostat

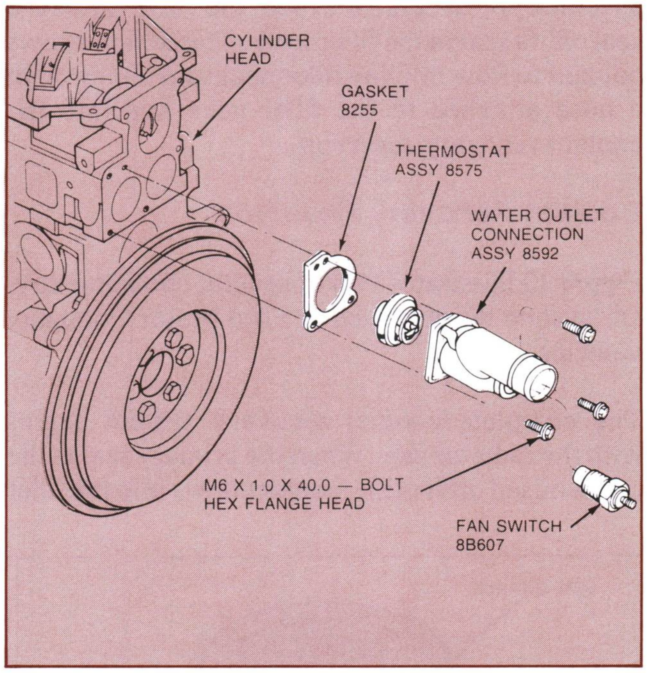

CYLINDER HEAD
GASKET 8255
THERMOSTAT ASSY 8575
WATER OUTLET CONNECTION ASSY 8592
M6 X 1.0 X 40.0 — BOLT HEX FLANGE HEAD
FAN SWITCH 8B607

Figure 14. Thermostat Installation - 4-Cylinder Engine

Two of several types of thermostat installations are shown in Figures 14 and 15. The first is an installation used in a smaller engine. Notice that

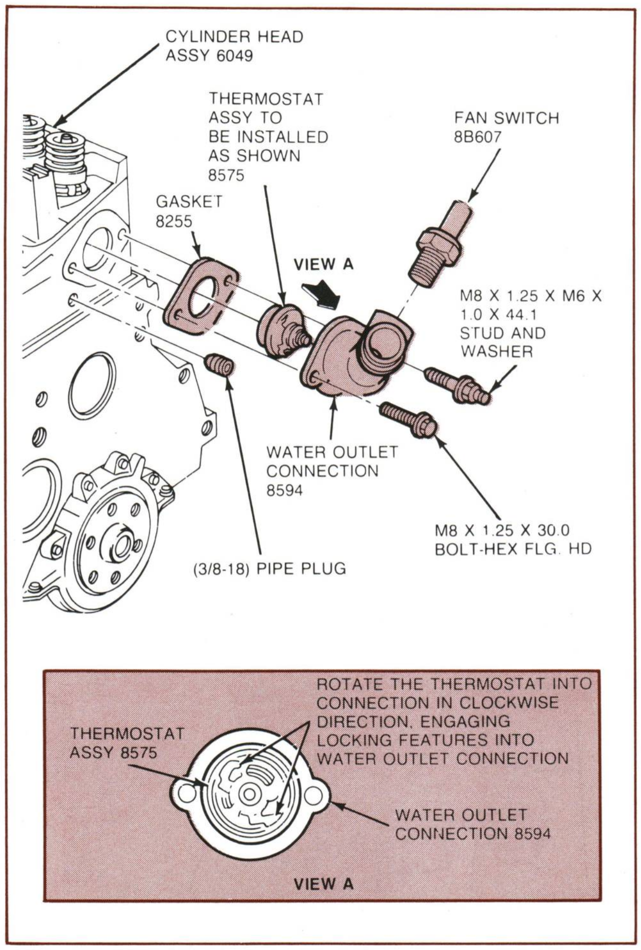

CYLINDER HEAD ASSY 6049
THERMOSTAT ASSY TO BE INSTALLED AS SHOWN 8575
FAN SWITCH 8B607
GASKET 8255
VIEW A
M8 X 1.25 X M6 X 1.0 X 44.1 STUD AND WASHER
WATER OUTLET CONNECTION 8594
M8 X 1.25 X 30.0 BOLT-HEX FLG. HD
(3/8-18) PIPE PLUG
ROTATE THE THERMOSTAT INTO CONNECTION IN CLOCKWISE DIRECTION, ENGAGING LOCKING FEATURES INTO WATER OUTLET CONNECTION
THERMOSTAT ASSY 8575
WATER OUTLET CONNECTION 8594
VIEW A

Figure 15. Thermostat Installation - Larger 4-Cylinder Engine

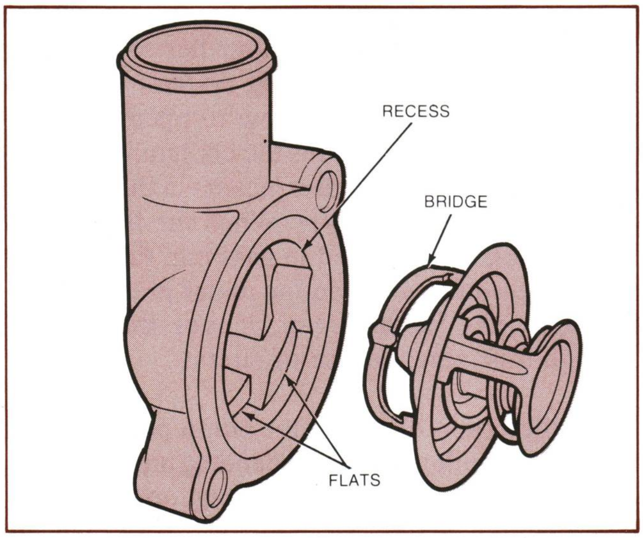


Figure 16. Thermostat Housing and Thermostat - V-6/V-8 Installation

the outlet side of the thermostat faces toward the front of the vehicle. Not shown in Figure 14 is the fact that the thermostat seats in the water connection is two steps: first, under hand pressure, and then, with clockwise rotation to lock it in place. Figure 15 shows a typical thermostat installation in a larger 4-cylinder engine. The configuration of the water outlet connection differs from that shown in Figure 14. In other respects, the installations are similar. View A highlights the locking feature for the thermostat in the water outlet connection.

In both Figures 14 and 15, the coolant temperature switch which energizes the engine cooling fan is called out. Remember that this switch will close and complete the fan circuit when the temperature reaches its specified level (approximately 221°F) to require the extra cooling. Also remember that the cooling fan, regardless of temperature conditions, will be operating whenever the A/C compressor is operating.

In V-6 and V-8 engines, the thermostat seats in a housing which attaches to the intake manifold. Figure 16 shows a typical thermostat housing for this type of engine as well as its component thermostat.

Water Pump

The engine crankshaft and its pulley are the initial driving force for the other pulleys, sprockets, or chains which provide the rotary motion needed to operate components such as the water pump. Figure 17 illustrates one type of belt and pulley installation. In this case the example shows the transfer of power by belts from the crankshaft pulley to a belt tensioner pulley and, from there, to the water pump pulley and back to the crankshaft pulley. The inset view in Figure 17 shows how the tensioner pulley is mounted and identifies the bolt which is used to adjust the amount of tension in the belt.

On those engines which have an electro-drive cooling fan, the water pump pulley is not involved in cooling fan operation. The transversely mounted engine also requires an electro-drive cooling fan which requires no belt drive.

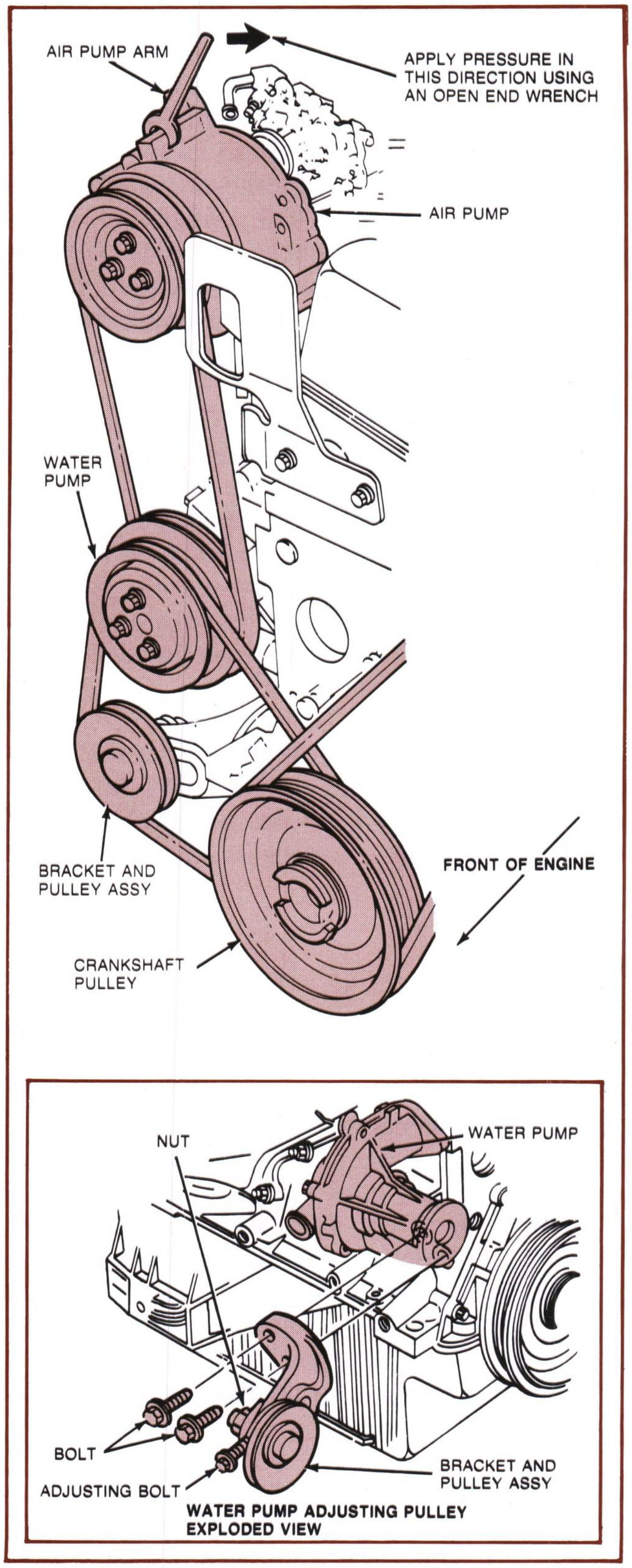


Figure 17. Belt-driven Water Pump and Belt Tensioner

The larger V-6 and V-8 engines, on the other hand, use a fan with a fan drive clutch which attaches to the belt-driven water pump. Details regarding this fan drive clutch will be provided later in this section under the heading "Fan Drive Clutch and Fan."

Figure 18 shows a water pump from which the pulley has been disassembled and the radiator lower hose, heater hose, and water pump by-pass have been disconnected.

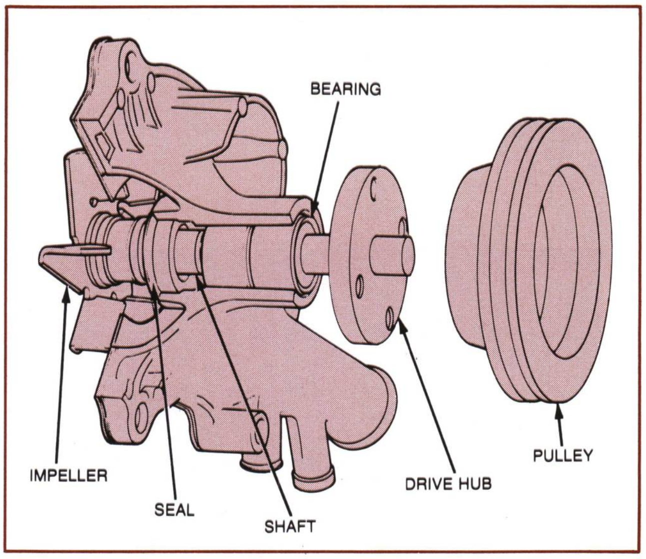


Figure 18. Water Pump and Related Parts

Functionally, the water pump is a centrifugal pump which uses its vaned impeller to circulate coolant throughout the cooling system. When the coolant temperature is too low to open the thermostat, the pump circulates the coolant in a recurring cycle through the water jackets in the cylinder block and cylinder head(s). When the thermostat opens, coolant is allowed to pass into the radiator core. The water pump, acting under pressure sustained by the radiator cap, moves the coolant through this added length of circuit.

The pulley ratio of the water pump pulley to the crankshaft pulley varies depending upon engine size, vehicle make, and cooling options. For example, the water pump pulley to crankshaft pulley ratio for a given vehicle with a 5.0L engine, with or without A/C is 1.13:1. A vehicle with a fan

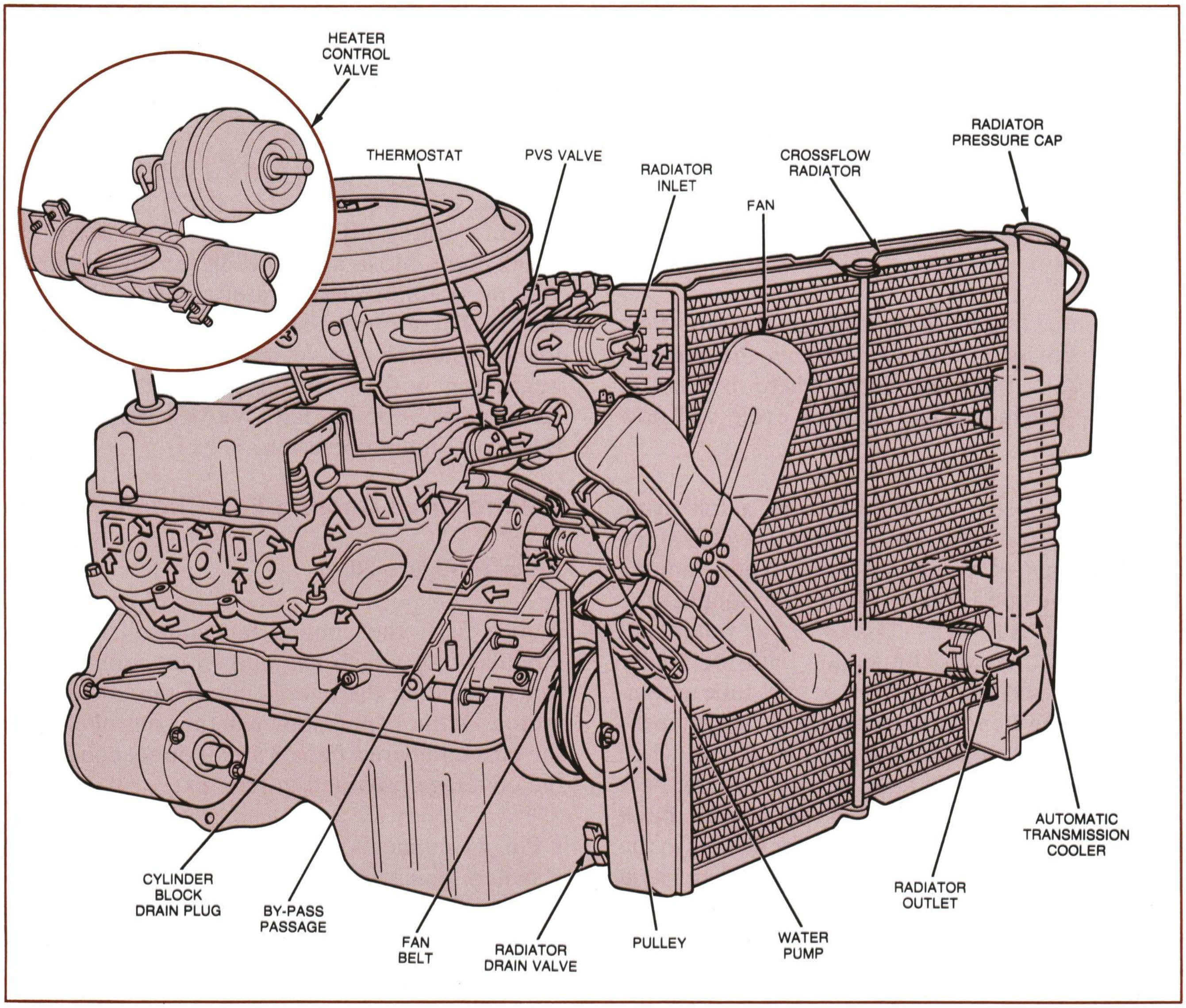


Figure 19. Coolant Flow Cycle

drive clutch, 5.0L engine, and A/C uses a water pump pulley at a 1.36:1 ratio. In terms of engine rpm, this means that a pump rotation of 2000 rpm requires 1770 engine rpm for the 1.13:1 ratio and 1470 engine rpm for the 1.36:1 ratio.

THE COMPLETE COOLING CYCLE (A REVIEW)

Coolant Flow

Up to this point, the text has dealt separately with the components which collectively constitute a cooling system. Now, for its review value, it will trace a cooling cycle through these components. Refer to Figure 19 and follow the course of the coolant flow from the water pump through a full cycle back to the water pump.

Whenever the engine crankshaft pulley is rotating, the belt-driven water pump pulley is also rotating at a speed somewhat faster than engine rpm. The energy generated by the pump forces coolant through the water jackets in the cylinder block and cylinder head(s). A water outlet connection which attaches, in most cases, to the cylinder head houses the thermostat and the cooling fan temperature switch. This connection receives the output from the cylinder head, and, when the thermostat is open, directs coolant past the fan control switch and through the upper radiator hose. Next, considering only the crossflow radiator design, the coolant courses through the horizontal pipes. All of this action takes place under pressure from the water pump which is capable of moving the coolant through the system at a rate of approximately 125 gallons-per-minute.

After completing its travel through the crossflow circuit, coolant is directed through the radiator lower hose to the water pump where, by choice, the cycle originated and another cycle will now begin.

These have been the highlights of a full cycle through the cooling system. There are also some review items of particular importance, among which we include a coolant circuit that supplies the heater core. As shown in Figure 19, the water inlet tube makes a circuit connection with the heater return hose and the heater water inlet tube assembly. Another item of importance is the by-pass outlet in the water outlet connection. There, when the thermostat is closed and cuts off coolant flow to the radiator, the cycle is by-passed back through the water pump to the water jackets in the cylinder block and cylinder head(s). Then, as a third item which warrants attention in our review, the transmission oil cooler lines operate as a closed circuit which directs transmission oil in and out of the oil cooler assembly installed inside the radiator outlet tank.

ELECTRICAL CIRCUITS

Electro-drive Cooling Fan

Airflow through the radiator is frequently insufficient to maintain the desired coolant temperature in the closed engine coolant circuit we have just described. During combustion, the temperature in the combustion chamber may range from a low of approximately 1200°F to a high of 4500°F or more. It is the job of the cooling system to dissipate approximately one-third of this heat. How well it handles its job, in addition to the suitability of radiator design, depends upon other factors such as ambient temperature, the rate of airflow through the radiator core, water pump capacity, engine load, and the opening and closing temperatures of the thermostat.

The engine cooling fan plays a significant role in providing the desirable rate and volume of airflow. At one time, all fans were driven by the crankshaft. Most are now driven by either an electric motor or a temperature sensitive fan drive clutch. Therefore, as supplementary information to our system review, let us describe fan operation beginning with a circuit which energizes an electro-drive cooling fan. We will then describe fan drive clutch operation.

Electro-drive Cooling Fan Circuit

Refer to Figure 20.

Notice first, the cooling fan controller. It is a modular unit which has numerous control functions including the energizing of the cooling fan motor. Of the 10 pins shown in the controller, only the pins numbered 1 and 3 are of direct concern to the coverage provided in this text.

- Pin #1 connects with the coolant temperature switch which has its own external ground circuit. When the coolant temperature rises to the point where the switch contact closes, a circuit is completed between the switch and the controller. The controller then directs this input to its Pin #3.
- Pin #3 connects with the externally grounded cooling fan motor and this completed circuit energizes the motor.

Figure 20 indicates which of the remaining pins serve other electrical circuits. It is emphasized that the pin numbers called out apply to the illustration only. The numbers may differ between controller applications. Be sure to check the appropriate shop manual for the circuit which applies to a given vehicle.

Some vehicles may not be equipped with a cooling fan controller even though they have an electro-

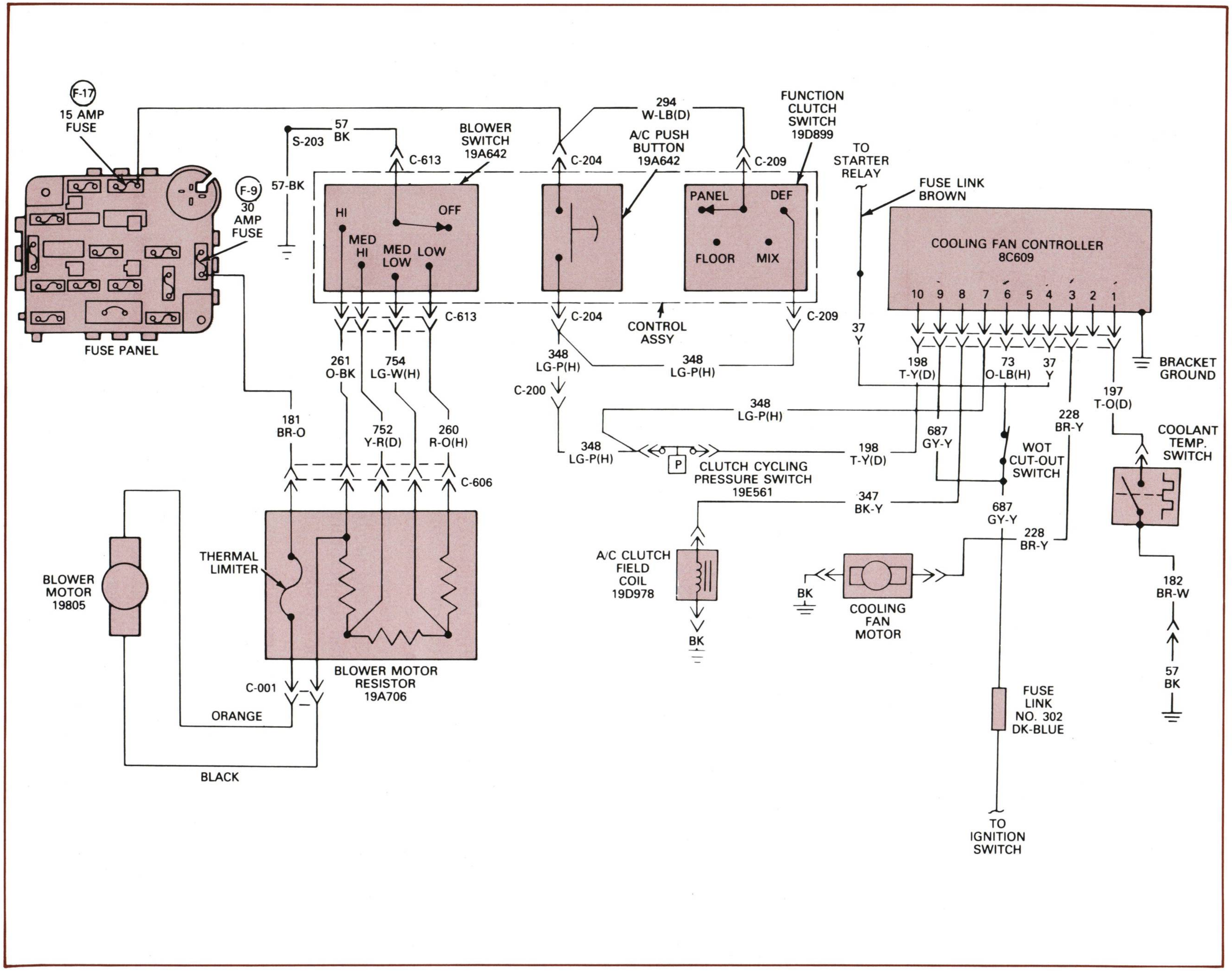


Figure 20. Electro-drive Cooling Fan Circuit

drive cooling fan. In these cases, the motor is energized directly when the coolant temperature switch contact closes.

Electro-drive cooling fan applications include vehicles with a transversely mounted engine and a transaxle. Some front wheel drive vehicles use an integral relay module which includes a separate relay for low speed and high speed fan operation, as well as relays for other functions not involved with cooling. The motor-driven fan is also being used on some rear wheel drive vehicles which, because of their special design features, have extra cooling requirements. Still another example of an electro-drive cooling fan application can be found in some rear wheel drive vehicles with a turbocharged engine. In those applications, because of the additional cooling needed, not one, but two motor-driven fans are used to provide two separately controlled fan speeds.

Figure 21 pictorially illustrates an electro-drive cooling fan and one of several types of controllers used to handle fan operation.

Cooling Fan Temperature Switch

Depending upon the vehicle line and the engine which has been installed in that vehicle, the fan motor will be energized by the cooling fan temperature switch alone or through the switch to a cooling fan controller and then to the motor. This switch is located in the heater hose tube in some of the mid-size vehicles when they are equipped with one of the various versions of the 2.3L engine. In the smaller vehicles, the cooling fan temperature switch is located in the thermostat housing.

Coolant Temperature Gauge Circuit

With the ignition switch in the accessory (ACC) position or the run (ON) position, an instrument voltage regulator located in the instrument cluster supplies a pulsating output voltage (approximately 5 volts) to both the coolant temperature gauge and the fuel gauge. The coolant temperature gauge connects with the coolant temperature sender which is a temperature sensitive variable resistor. When the coolant temperature is low, resistance is high; when the coolant temperature is high, resistance is low. Figure 22 is a diagram of the circuit involved.

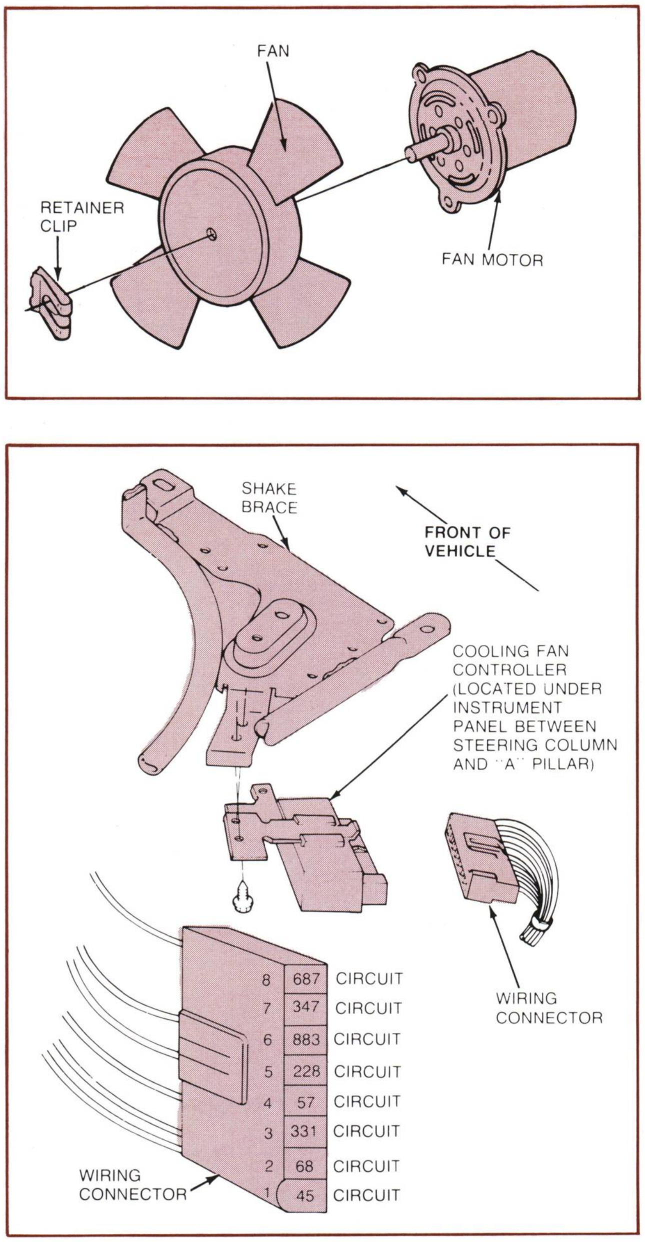


Figure 21. Electro-drive Cooling Fan and Controller

Fan Drive Clutch and Fan

Those vehicles which are not equipped with an electro-drive cooling fan will have a fan operated by a drive clutch. Figure 23 illustrates the components involved.

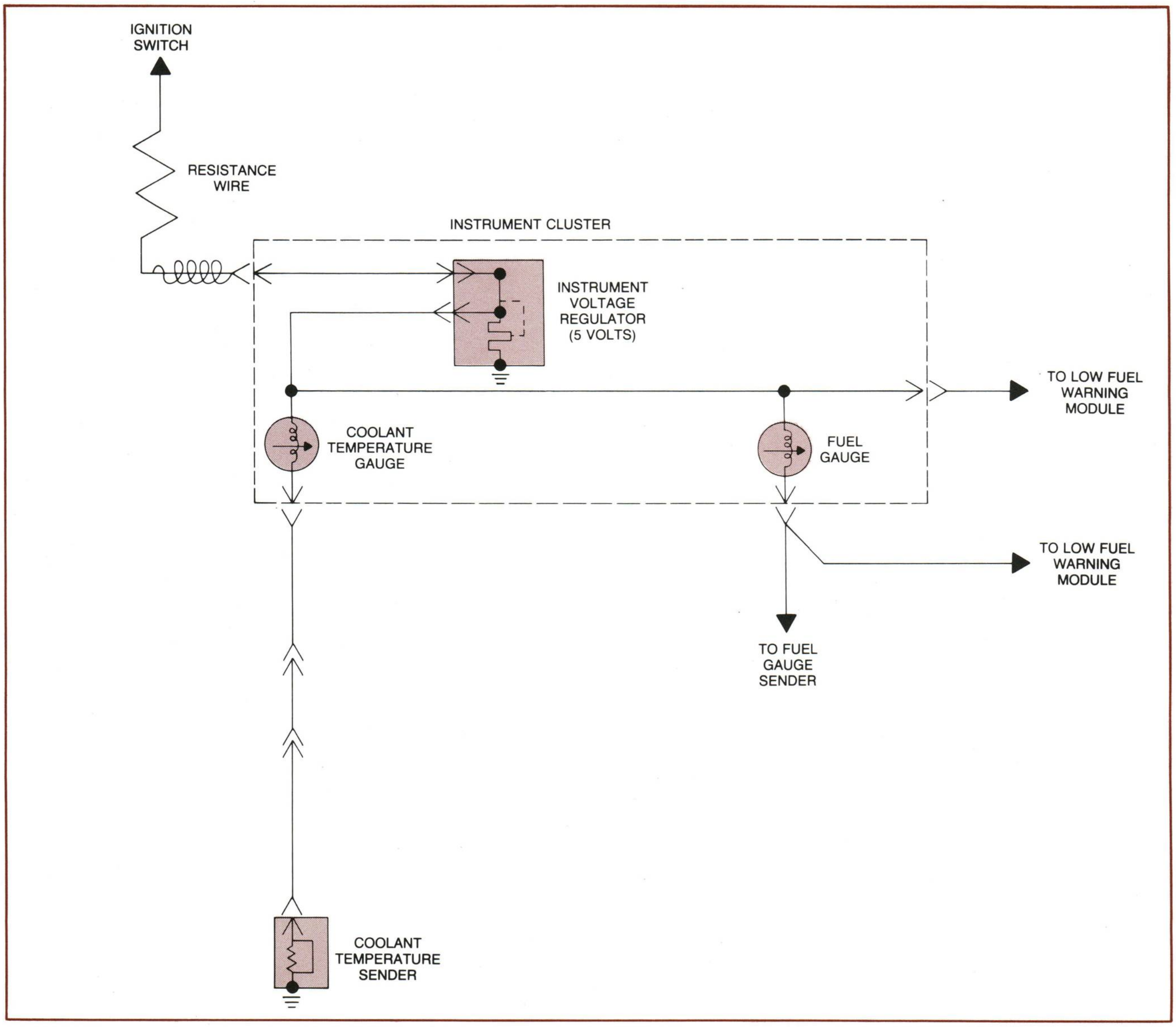

IGNITION SWITCH
RESISTANCE WIRE
INSTRUMENT CLUSTER
INSTRUMENT VOLTAGE REGULATOR (5 VOLTS)
TO LOW FUEL WARNING MODULE
COOLANT TEMPERATURE GAUGE
FUEL GAUGE
TO LOW FUEL WARNING MODULE
TO FUEL GAUGE SENDER
COOLANT TEMPERATURE SENDER

Figure 22. Coolant Temperature Gauge Circuit

The fan is attached to the rear surface of the clutch with four bolts. The clutch and fan assembly attaches to the hub on the belt-driven water pump.

The fan clutch is basically a temperature controlled fluid coupling which regulates fan speed within a specified range based upon engine cubic inch (liter) displacement, vehicle application, and cooling system options.

The controlling factor for fan operation is the temperature of the air passing through the radiator core. A bimetal control spring on the front face of the clutch senses the temperature of the air coming from the radiator core and operates a control valve which adjusts fan speed to accommodate temperature changes.

Drive Belts and Pulleys

Figure 24, View A illustrates three types of drive belts: (1) the conventional ''V'' belt, (2) the cogged ''V'' belt, and (3) the ''V'' ribbed belt. Contingent upon the displacement rating of the engine involved and the accessory pulleys which that engine will be driving, the manufacturer installs the

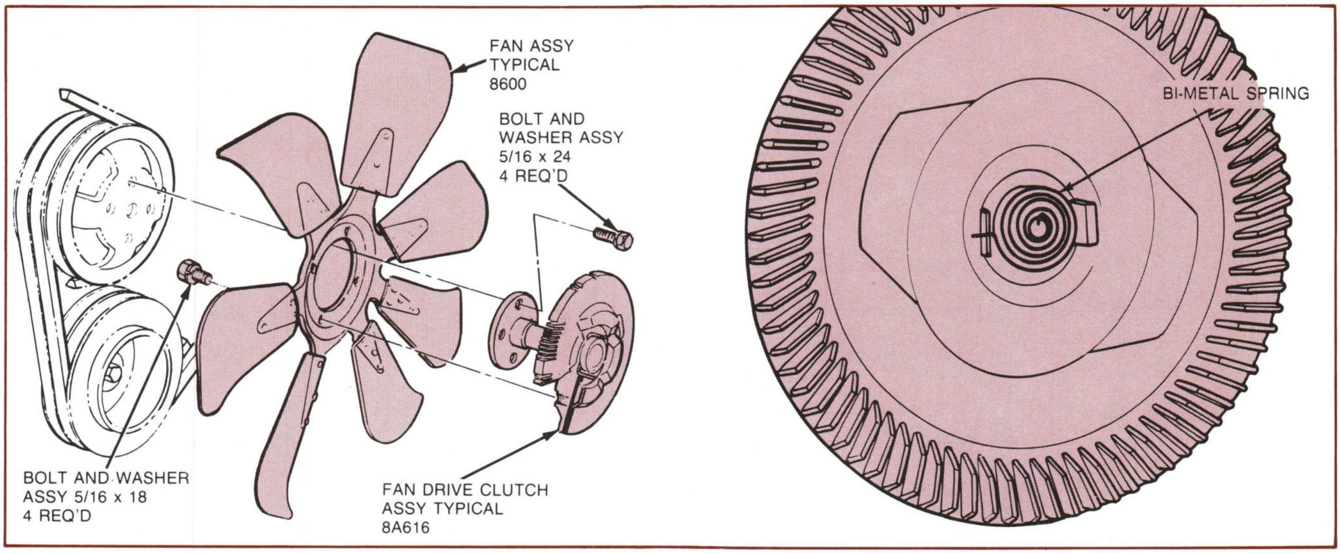


Figure 23. Fan Drive Clutch and Fan

type of belt that will best accommodate the specific system. With this in mind, a service replacement belt must match its original equipment predecessor.

As Figure 24, View B shows, a belt may establish a single link between a drive and driven pulley; or, as shown in View C, all three belt designs may be used in a single installation. The water pump pulley and water pump adjustment pulley are highlighted in Views B and C. Finally, in View D, a single "V" ribbed belt is serpentine routed to operate all pulleys. The crankshaft pulley, in this case, is driving pulleys for the thermactor air pump, alternator, idler pulley, power steering pump, A/C compressor, and water pump.

Belt tension adjustment procedures are described later in the text under "Cooling System Fluids, Chemicals, and Maintenance."

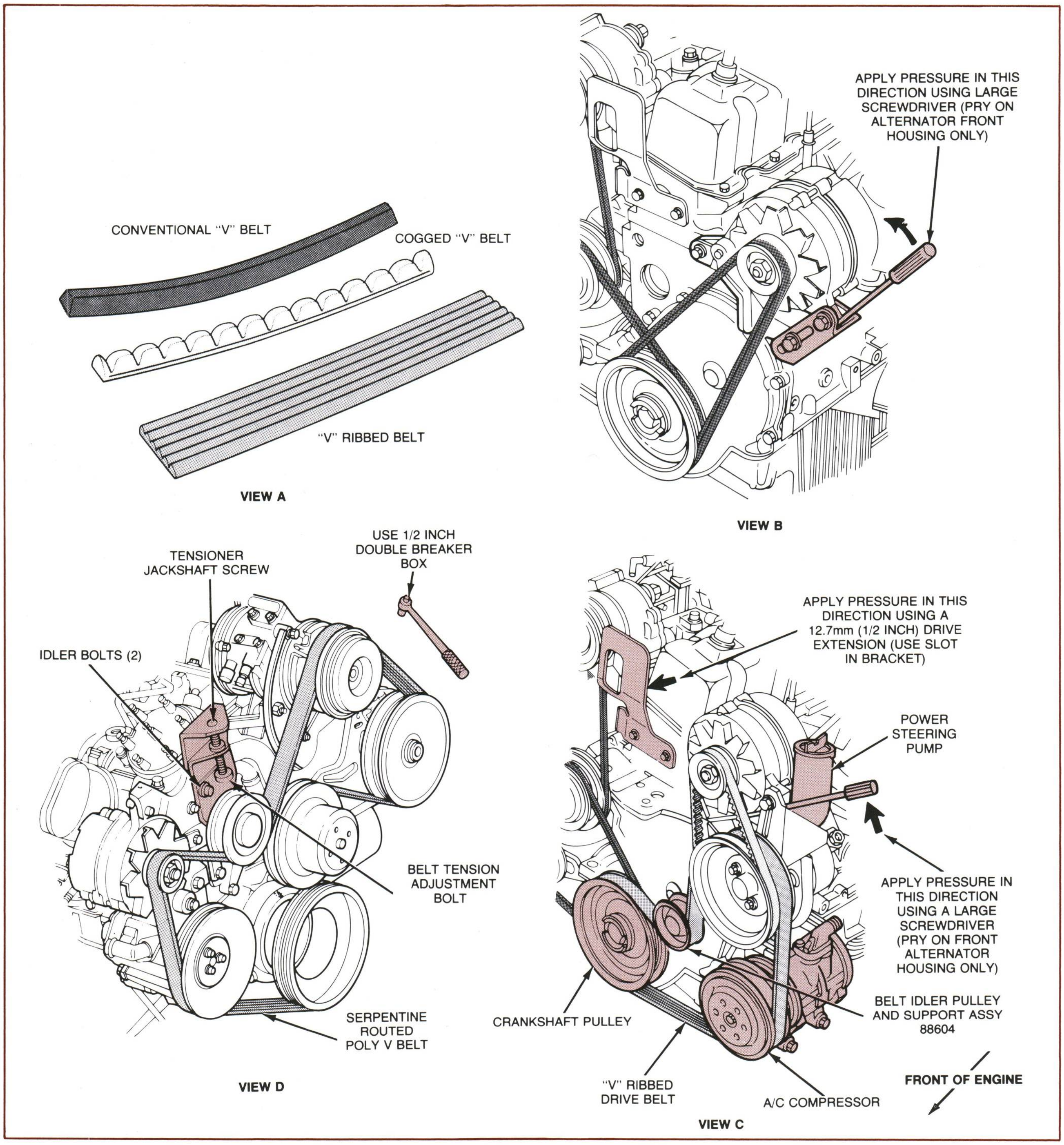

CONVENTIONAL "V" BELT
COGGED "V" BELT
"V" RIBBED BELT
VIEW A
APPLY PRESSURE IN THIS DIRECTION USING LARGE SCREWDRIVER (PRY ON ALTERNATOR FRONT HOUSING ONLY)
VIEW B
TENSIONER JACKSHAFT SCREW
USE 1/2 INCH DOUBLE BREAKER BOX
IDLER BOLTS (2)
BELT TENSION ADJUSTMENT BOLT
SERPENTINE ROUTED POLY V BELT
VIEW D
APPLY PRESSURE IN THIS DIRECTION USING A 12.7mm (1/2 INCH) DRIVE EXTENSION (USE SLOT IN BRACKET)
POWER STEERING PUMP
APPLY PRESSURE IN THIS DIRECTION USING A LARGE SCREWDRIVER (PRY ON FRONT ALTERNATOR HOUSING ONLY)
BELT IDLER PULLEY AND SUPPORT ASSY 88604
CRANKSHAFT PULLEY
FRONT OF ENGINE
"V" RIBBED DRIVE BELT
A/C COMPRESSOR
VIEW C

Figure 24. Drive Belt and Pulley Installations

INTERACTION OF THE COOLING SYSTEM WITH OTHER VEHICLE SYSTEMS OR COMPONENTS

The cooling system provides heated coolant to the heater core. It provides a heat exchanger function for the transmission oil cooler. It competes with the A/C condenser for an adequate supply of cooling airflow. It has a control function in the operation of certain temperature sensitive vacuum switches. These are some of the ways in which the cooling system interacts with other systems and components. Some comments follow regarding this interactivity.

Heating System

The engine cooling system has a functional role in the performance of the passenger compartment heating system. Figure 19, shown previously, illustrates a heater core and heater lines as part of a total cooling system. The core in most current Ford applications is housed in an A/C evaporator case. Figure 25 is a diagram of an evaporator case which shows it containing a heater core, blower motor, and manual and vacuum controlled air distribution doors. (The open space in the center of the case would be occupied by an evaporator core if air conditioning was involved.)

Water Control Valve

Many heater and combination heater/air conditioning systems have a water control valve operated by a vacuum motor. Figure 26 illustrates a typical valve and motor installation.

This valve controls the flow of coolant through the heater core. Early designs of this valve were normally closed until vacuum was applied; later designs were normally open until vacuum was applied. The change ensured that heated coolant

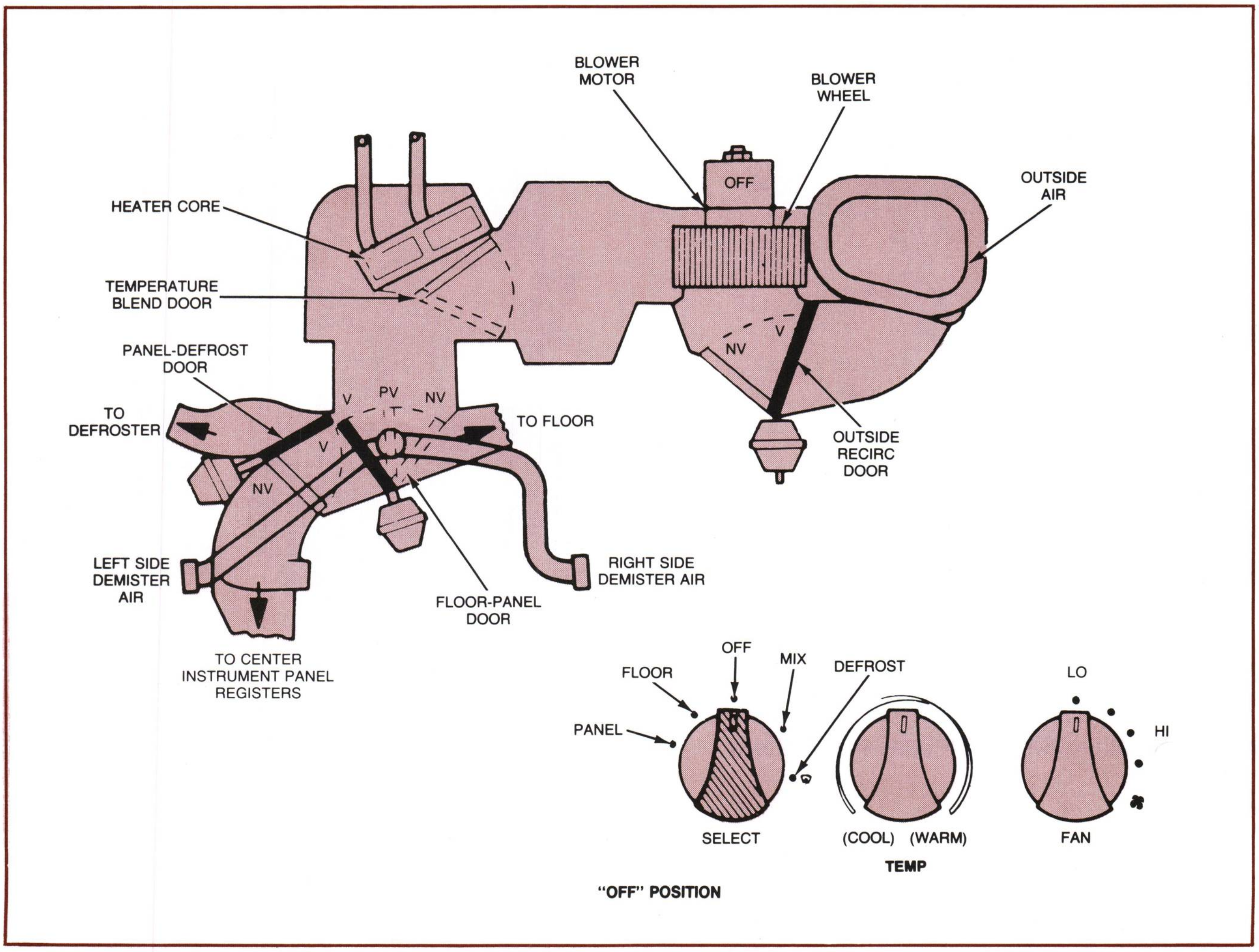


Figure 25. Heater Core Location

flow would be available for defrosters even though other heater system components should malfunction.

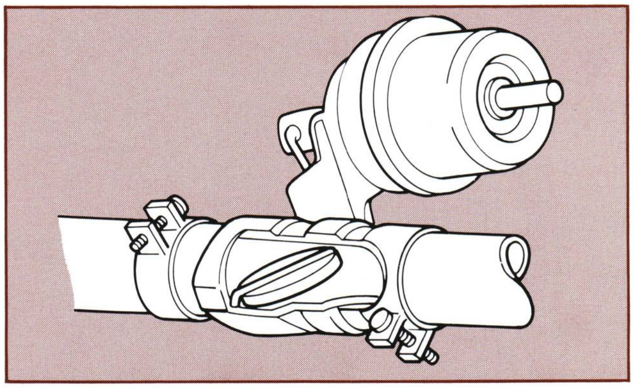


Figure 26. Water Control Valve

Ported Vacuum Switch

Again referring to Figure 19, notice that it calls out a ported vacuum switch. A closer view of this switch is provided in Figure 27.

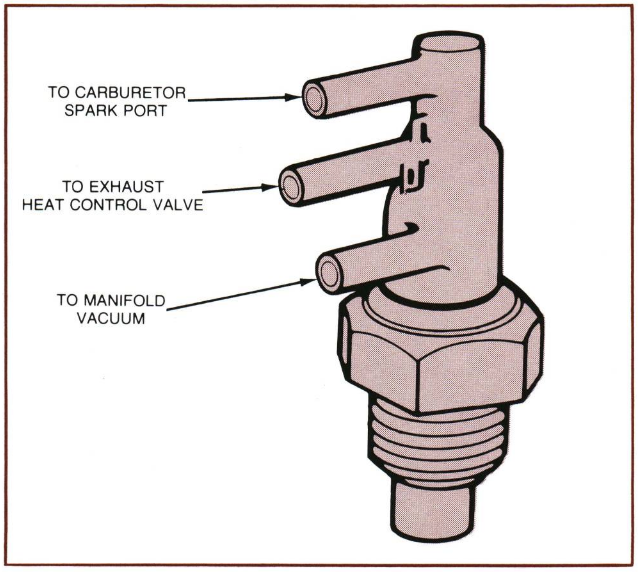


Figure 27. Ported Vacuum Switch (PVS)

The ported vacuum switch may have 2, 3, or 4 ports each operating vacuum switches in response to coolant temperature conditions. A typical 3-port PVS is shown in the illustration. It is sometimes used in the coolant system to increase the engine idle rpm if the engine overheats. At other times, a PVS is used to control operation of an exhaust heat control valve.

On some models, under stabilized coolant temperatures, the PVS provides carburetor spark port vacuum to the distributor vacuum advance. On others, the idle speed is controlled electronically. If the coolant becomes abnormally hot, the PVS automatically switches to manifold vacuum to increase spark advance. The change in advance increases engine idle speed. When the coolant returns to its normal temperature, carburetor spark port vacuum is again introduced. When this happens, the spark retards causing the engine idle speed to decrease.

A/C Condenser

The air conditioning condenser is not a cooling system component, but is a factor in cooling system efficiency. Figure 28 shows that the condenser is installed directly in front of the radiator assembly.

Its position in the extreme forward end of the engine compartment reduces the rate and volume of airflow through the radiator. It also raises the temperature of the air being drawn through the radiator by the engine cooling fan. In addition to these normal restrictions to airflow, there is an additional potential for serious restriction if the condenser is allowed to be clogged with foreign matter, such as leaves, snow or mud.

OTHER CONDITIONS AFFECTING COOLING SYSTEM EFFICIENCY

There are several other conditions that might exist outside the cooling system which could have an undesirable affect on its efficiency:

- Overly retarded ignition timing will cause an engine to overheat.
- Restrictions in the exhaust system will lead to engine overheating.
- In addition to the difficulty which will be experienced if the transmission oil cooler is not functioning properly, inadequate adjustment of automatic transmission components and/or insufficient transmission fluid will result in an overheating of the transmission and concur-

INTERACTION OF THE COOLING SYSTEM WITH OTHER VEHICLE SYSTEMS OR COMPONENTS

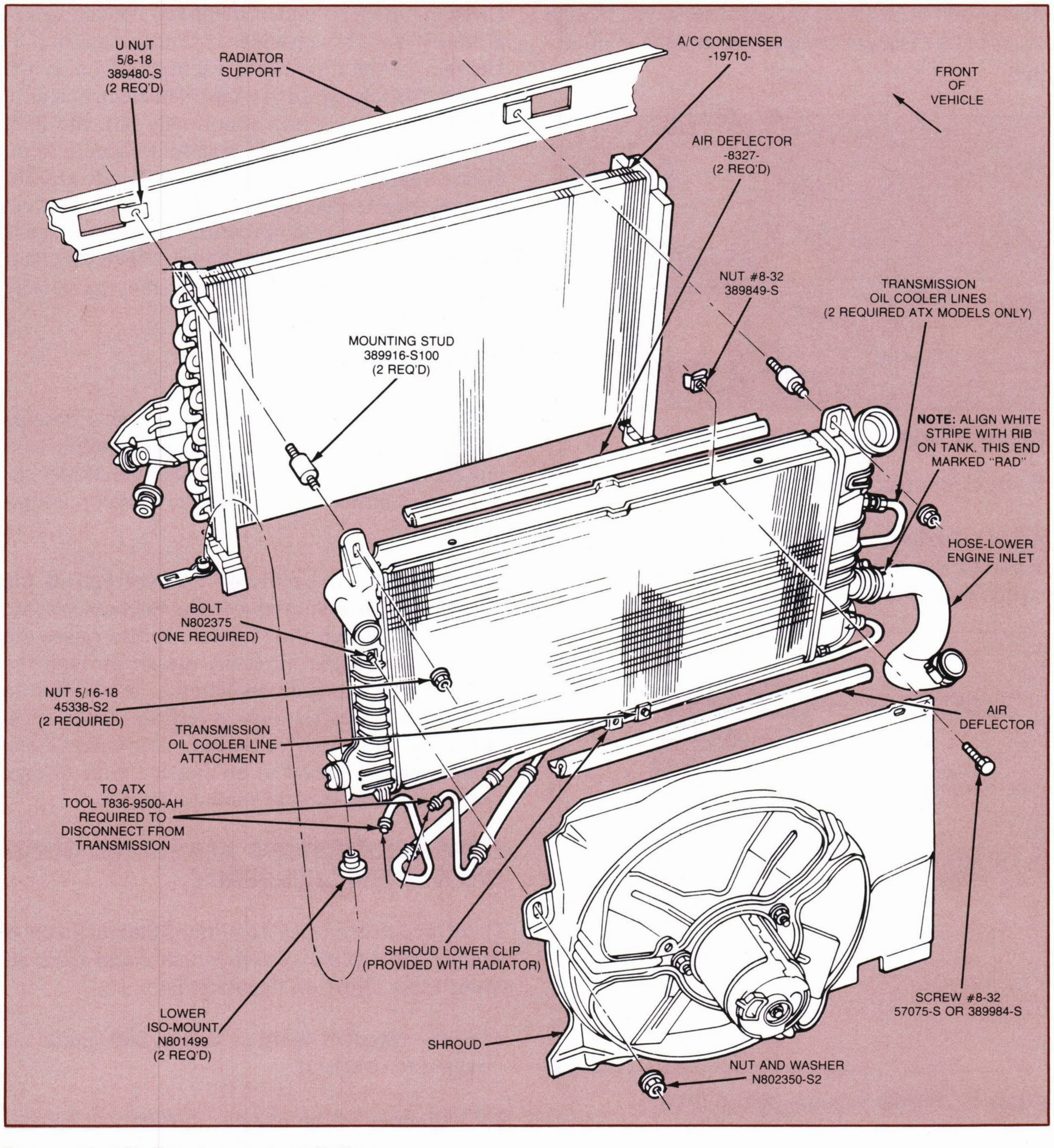


Figure 28. A/C Condenser Installation

rently an overheating of the engine coolant.

- Exceeding the loads that an engine and transmission are designed to handle will result in overheating. In this respect, a trailer and its load or another vehicle which is being towed should be (1) properly secured to the vehicle providing the tow and (2) should be within specified limits for towing weight. An approved trailer towing package is an important step toward safe, trouble-free towing. Consideration of the wind resistance that a given trailer design will introduce is another step toward a successful towing project. Properly preparing a vehicle for over-the-road transport is still another step to take to minimize the possibility of causing the engine to overheat in the vehicle providing the tow.

- Dragging brakes will cause the linings to ''fry'', glaze, and wear down well ahead of their design life. They will place an unnecessary load on the engine and transmission and cause overheating in both assemblies if the condition is allowed to persist.

These are some of the unfavorable conditions which might originate outside the physical confines of the cooling system which could relay their poor performance results to a corresponding poor performance in the cooling system.

COOLING SYSTEM FLUIDS, CHEMICALS, AND MAINTENANCE

COOLING SYSTEM FLUIDS

The Ford Motor Company tests its cooling system fluids to determine which type and concentration of fluid will best meet the needs of the various systems designed for its product lines. As a result, the fluid selected is assigned a Ford Specification Number and subsequently a Ford Service Part Number. An example of these numbers is: (1) Ford Specification Number ESE-M97B44-A and (2) Ford Service Part Number EF2Z-19549-A.

Again, the Company recommendation is to mix the coolant in a 50/50 mixture. This mixture is most easily obtained by filling the radiator to half of its capacity with undiluted anti-freeze, and then, to full capacity with water.

The quantity of the mixture needed will vary depending upon the engine displacement and in some cases upon the type of fuel system, the type of transmission, and whether or not air conditioning is included in the vehicle. Even a trailer tow package calls for a larger coolant supply. Because of these variations, coolant capacities may range from 6.8 quarts for a small engine with a manual transmission, transaxle, and air conditioning to 16.2 quarts for a large, high output engine with an automatic transmission, air conditioning, and a trailer towing package. With this much variation in cooling system capacity, it is essential that the shop manual be checked if exact capacity information is needed.

Anti-freeze Protection

Plain water is considered to be an excellent coolant because of its inherent heat transfer characteristics. Unfortunately, its comparatively high freezing point and low boiling point limit its suitability for use as an internal combustion engine coolant.

When water freezes, it expands approximately 9% in volume. This expansion could be enough to crack the solder joints or fracture the tubes in a radiator. It may even be enough to crack the cylinder block. At the other end of the scale, when water reaches its boiling point, it vaporizes and loses its value as a cooling agent.

The text mentioned earlier, in its coverage of system pressurization, that ethylene glycol is a basic component of most anti-freeze solutions. To this base most manufacturers add rust and corrosion inhibitors. Then, to the solution of ethylene glycol and inhibitors, water is added when filling the radiator to provide a 50/50 mixture.

Diluting the anti-freeze is important. Pure ethylene glycol turns into a gel-like consistency at -8°F. Without its fluid characteristics, it becomes ineffective as a cold ambient protection against freezing. Figure 29 is a bar graph which illustrates the water to ethylene glycol comparative protective range at both ends of the temperature scale.

Because permanent anti-freeze has a higher boiling point than either water or the now rarely used alcohol based solutions, it does not evaporate easily. In fact, whatever evaporation does occur is probably attributable to the boiling or evaporation of the water content in the solution.

Depending upon where the dealership receiving a new car delivery is located, production will install the mixture of anti-freeze and water called for on the production process sheet. For example, the mixture for most delivery areas will protect the system against freezing in ambient temperatures at or above-20°F (-29°C). If the delivery is to be made in an area of the United States, Alaska, or Canada where cold temperatures may be more extreme, freezing protection in the coolant mixture is increased to cover temperatures down to -35°F (-37°C).

Company recommendations to the customer are to have the anti-freeze protection level checked prior to each winter season, and have the coolant mixture in the radiator sufficiently concentrated to ensure minimum protection for a vehicle which may be operated in a -20°F ambient.

To accurately check the level of protection, use either a Rotunda Optical Anti-freeze/Battery

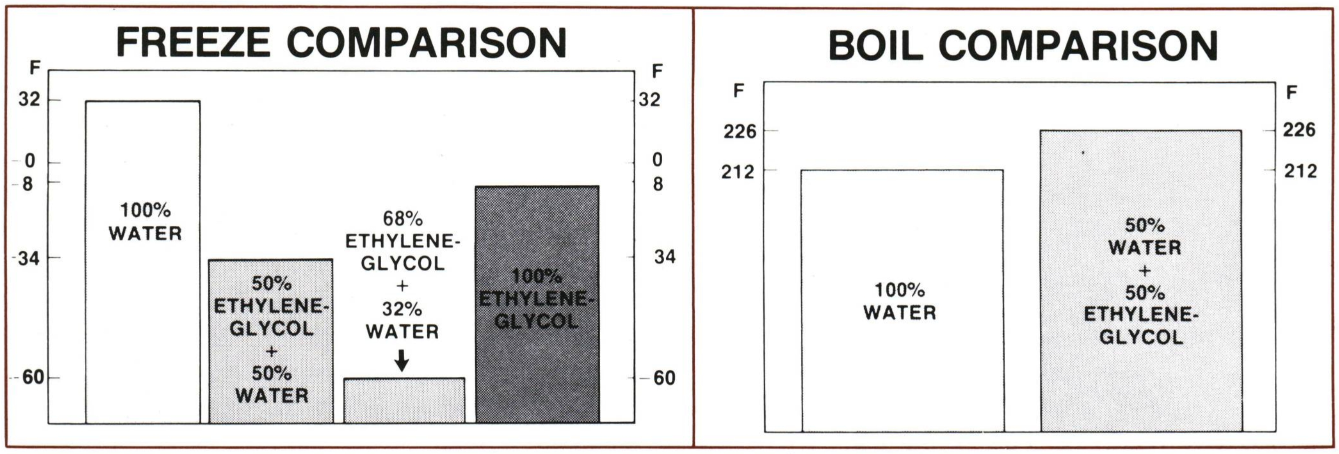


Figure 29. Water vs. Ethylene Glycol

Tester (Numbered 072-00005), or equivalent. An hydrometer is an acceptable substitute. Figure 30 illustrates both of these test devices.

Other Methods of Cooling System Protection and Maintenance

A Motorcraft/Ford Technical Service Bulletin numbered 79-16, dated April, 1979, reports recommendations regarding the selection and use of chemicals in a cooling system. Comments about some of these chemicals follow.

Stop-leak Chemicals

Motorcraft Protector Powder, Part Number RA-2, is packaged as illustrated in Figure 31. This powder will help seal and prevent leaks in the radiator, head gasket, block, and hose connections. It is recommended as a regular maintenance additive when draining and refilling the radiator or after the cooling system has been flushed. The powder is added directly to the coolant through the radiator filler neck.

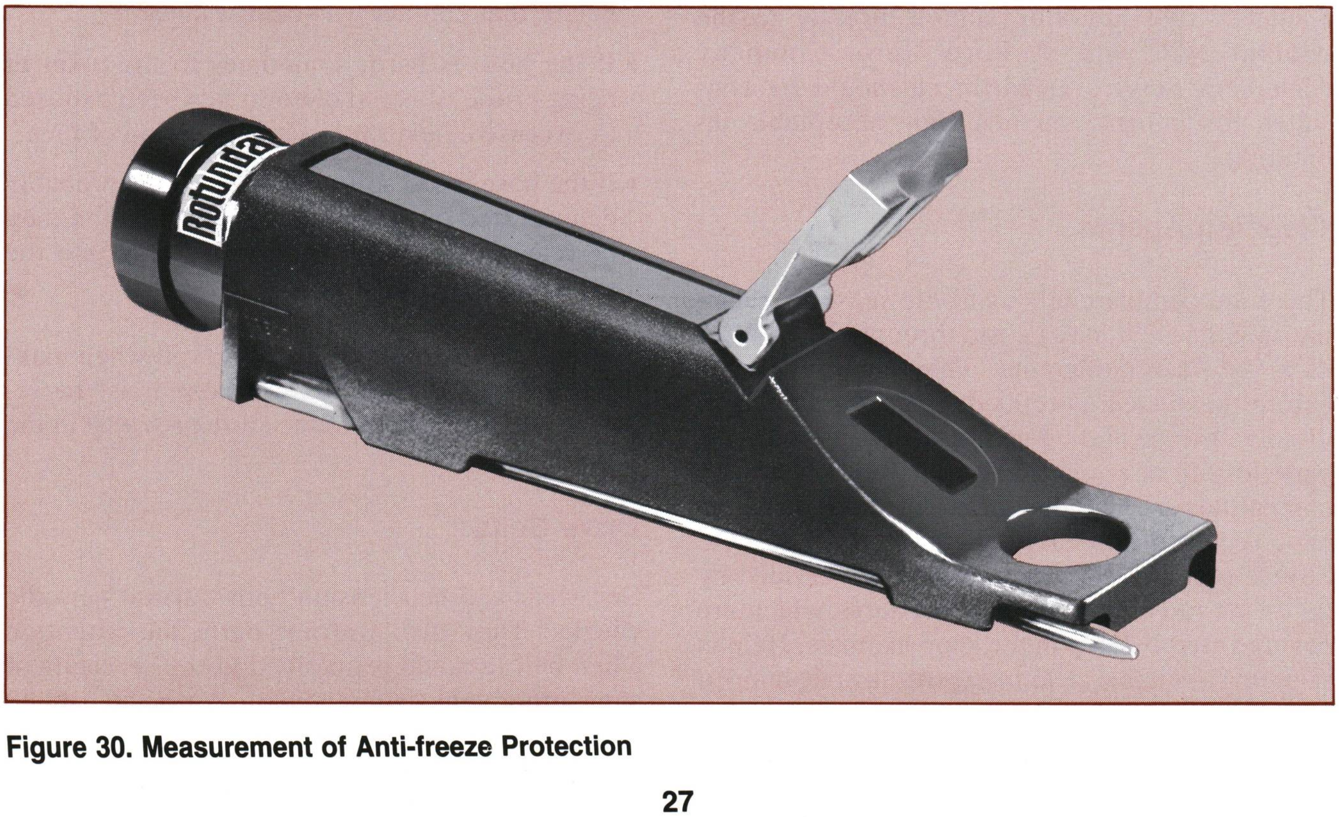


Figure 30. Measurement of Anti-freeze Protection

Motorcraft
Cooling System Protector Powder
Seals and prevents leaks
Lubricates
Contains fluorescent leak detector

Figure 31. Cooling System Protector Powder

Rust Inhibitors

The most severe occurrence of rust in the cooling system is during hot weather when high engine temperatures accelerate the rate at which metal oxidizes. Minerals present in the water content of the coolant solution can build-up scale in the engine water jackets. To moderate these tendencies, a quality rust inhibitor, added directly to the coolant, will help. A Ford Motor Company dealership Service Department should be consulted for information regarding acceptable inhibitors.

Cleaning Agents

There are commercially available seasonal cleaning agents which may be run through the radiator as a fast-flush compound. They should be used before the system is refilled. Their purpose is to dissolve grease and oil and wash away loose rust particles. It is emphasized that these fast-flush compounds are intended for use in radiators which have received regularly scheduled maintenance. Severe rust and corrosion should be serviced by following radiator flushing procedures which are covered step-by-step in the shop manuals. Help in selecting a suitable cleaning agent may be obtained from the dealership.

Heater Core Backflushing

Because the fluid flow through the heater core is a tributary of the engine cooling system, flushing or backflushing the engine cooling system alone is not enough. The lines to and from the heater core and the core itself must be backflushed in conjunction with servicing the engine cooling system. It is emphasized that the heater core must be backflushed separately from the engine cooling system in order to obtain the proper direction for the backflush flow. Again, the shop manual covers the recommended procedure.

Radiator Hose Maintenance and Inspection

Unless there is visual evidence that a radiator hose is leaking, a hands-on check is perhaps the most frequently used method of determining whether a hose should remain in service. By running one's hands over the surface of a hose, one or more of the following conditions may be apparent:

- If the hose is in friction contact with another vehicle component, it will chafe.
- If the hose is in contact with the hot surface of an adjacent component, it will show burn marks where that contact was being made.
- If the hose is hard, sometimes to the point of being brittle, it is too old or it has been exposed to excessive heat for too long a period of time.
- If the hose is too soft or spongy, it has probably deteriorated internally. Such deterioration may be releasing particles of hose material into the system causing it to clog.

If any of these conditions is observed when making a maintenance check, the hose must be replaced according to the procedure provided in the shop manual.

Drive Belts

Belt wear and belt tension both warrant periodic checks. They also warrant particular attention when belt removal is involved in the servicing of some other vehicle component. Wear will usually

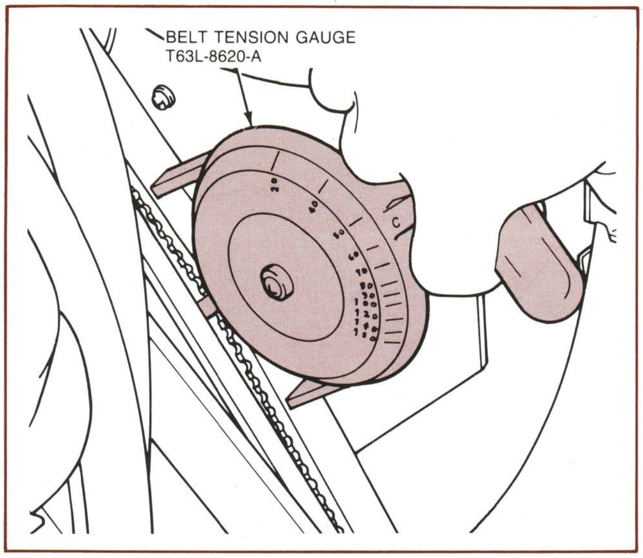


Figure 32. Belt Tension Gauge

show as a cracked surface along the side of the belt which contacts the pulley groove. Minor cracks in the opposite surface of the belt are less significant. Frayed belt material is an obvious sign of wear. Less apparent, but similarly responsible for inadequate belt performance, are a glazed driving surface and the presence of an oil slick on the surface of the belt.

An inoperative belt is a "CAR STOPPER." A loose belt will slip in the pulley grooves. If this happens, the accessory it drives is not performing properly, and it is most likely that a slipping belt will cause noise.

An overly-tight belt will add a damaging load to the bearings of the accessory being driven. This added load will increase the potential for premature bearing failure.

For best results when checking or adjusting belt tension, use a belt tension gauge, Tool Number T63L-8620-A, or equivalent. Application of this gauge is shown in Figure 32.

The use of a belt tension gauge is mandatory when servicing a V-ribbed belt. As an alternate method for checking and adjusting conventional V-belts and cogged V-belts, a thumb deflection method may be used. Refer to the shop manual for details.

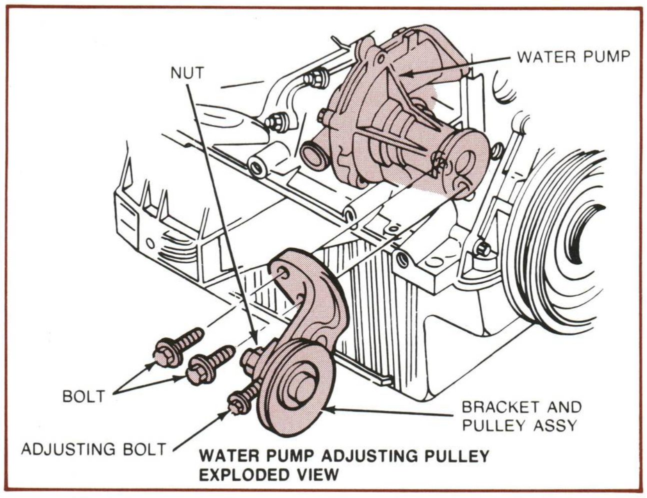


Figure 33. Water Pump Pulley and Adjusting Pulley

The procedure involved in water pump pulley belt adjustment for a typical engine is shown in Figure 33.

The inset view shows the water pump adjusting pulley attaching location and the adjusting bolt which increases or decreases the tension on the belt between the water pump pulley and the crankshaft pulley.

Belt tension procedures will vary from engine-to-engine depending upon the displacement rating and the number of accessories which are belt-driven. Figure 34 illustrates one of these variations.

The bolt torque, tension produced by the tension bolt, and belt tension are called out as letters in the illustration. They refer to specifications charted in the shop manual. Be sure to consult the appropriate shop manual for this specification data when servicing an actual vehicle.

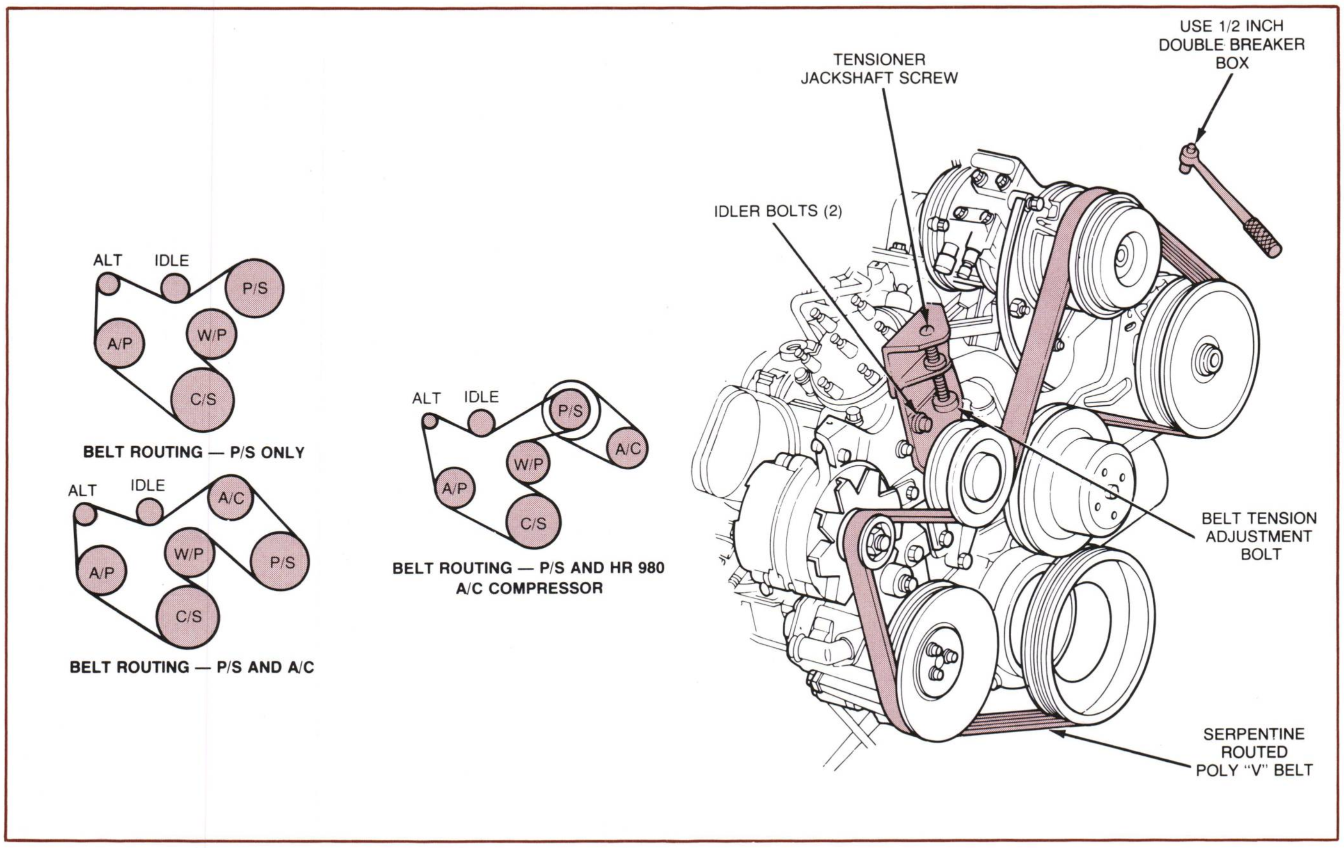

ALT
IDLE
P/S
A/P
W/P
C/S
BELT ROUTING — P/S ONLY
ALT
IDLE
A/C
A/P
W/P
P/S
C/S
BELT ROUTING — P/S AND A/C
ALT
IDLE
P/S
A/C
W/P
A/P
C/S
BELT ROUTING — P/S AND HR 980 A/C COMPRESSOR
TENSIONER JACKSHAFT SCREW
USE 1/2 INCH DOUBLE BREAKER BOX
IDLER BOLTS (2)
BELT TENSION ADJUSTMENT BOLT
SERPENTINE ROUTED POLY "V" BELT

Figure 34. Belt Tension Adjustment - 3.8L Engine Shown

Nearly all of the operating difficulties which might occur in a cooling system relate to leaks, engine overheating, or insufficient heat. For purposes of organization, Figure 35 charts these conditions, lists the possible sources that could cause it to occur, and then suggests the corrective action to take.

VISUAL INSPECTION

If the system is losing coolant without significantly overheating, the starting point is a visual inspection of the system. The points to inspect include:

1. Coolant and heater hose connections.
2. Seams in the radiator tanks.
3. Coolant trails coming from the radiator core tubes.
3. Radiator fin damage which may have penetrated a core tube.
4. Radiator drain petcock.
5. Cylinder block drain plugs.
5. All core plugs.
6. Edges of all cooling system gaskets.
7. Transmission oil cooler attachments on the radiator outlet tank.
8. Heater core tube connections at the heater core.
9. Water pump connections and the edges of the water pump gasket.
10. Reservoir tank and overflow tube.
11. Oil may be leaking into the coolant from the transmission oil cooler in the radiator outlet tank. If it is, it will show up as an oil slick visible through the filler neck opening. If, on the other hand, coolant is leaking into the transmission fluid, it will show up as beads of moisture on the transmission oil dipstick.
12. Radiator pressure cap.

    After making a visual inspection, a cooling system analyzer should be installed into the system to continue testing for functional suitability. Figure 30 illustrates this type of tester. Be sure that the manufacturer's operating instructions are observed.

PRESSURE TESTS

The cooling system is designed to operate under a sustained, controlled pressure to enable the coolant temperature to reach a desirable high. A pressure test pump and attachments (Rotunda Pressure Tester Number 021-00012, or equivalent) is available to check various system pressures. Figure 37 illustrates this tester.

Radiator Cap Pressure Test

To test radiator cap pressure alone, proceed as follows:

1. Immerse the radiator cap in water after making certain that the rubber seal and vacuum relief valve in the cap are thoroughly clean.
2. Install the cap on the radiator cap test adapter. See Figure 38.
3. Immerse the filler neck seal in water and install it on the filler neck adapter.

   Note: The filler neck seal is reversible so that it may be used in either a deep or shallow radiator filler neck. It will also fit into either end of the radiator cap test adapter.
4. Install the filler neck adapter and seal into the lower end of the radiator cap pressure adapter.
5. Connect the quick-connect female fitting on the test pump hose to the quick-connect male fitting on the filler neck adapter.
6. Slowly depress the pump plunger until the gauge reading no longer rises and remember or record the highest reading obtained.

   Note: Depressing the pump plunger too rapidly will produce a false reading.
7. Turn the pressure relief screw near the base of the gauge in a counterclockwise direction.

CONDITION	POSSIBLE SOURCE	ACTION
Loss of coolant	• Pressure cap and gasket.	• Inspect, wash gasket and test. Replace only if cap will not hold pressure test specification.
	• Leakage.	• Pressure test system.
	• External leakage.	• Inspect hose, hose connection, radiator, edges of cooling system gaskets, core plugs and drain plugs, transmission oil cooler lines, water pump, heater system components. Service or replace as required.
	• Radiator filler leak.	• Inspect radiator filler neck sealing surface for damage or foreign material.
	• Internal leakage.	• Check engine oil and transmission oil dipsticks for signs of coolant. Check coolant for signs of transmission oil. • Check torque of head bolts, tighten if necessary. • Disassemble engine as necessary — check for cracked intake manifold, blown head gaskets, leak at water crossover intake manifold gasket, warped head or block gasket surfaces, cracked cylinder head or engine block.
Engine overheats	• Low coolant level.	• Fill as required. Check for coolant loss.
	• Excessive rust in coolant.	• Flush system, refill with new coolant.
	• Loose fan belt.	• Adjust.
	• Pressure cap.	• Test. Replace if necessary.
	• Radiator or A/C condenser obstruction.	• Remove bugs, leaves, etc.
	• Closed thermostat.	• Test, replace if necessary.
	• Fan drive clutch.	• Test, replace if necessary.
	• Ignition.	• Check timing and advance. Adjust as required.
	• Temp gauge or cold light. (False reading)	• Check electrical circuits and service as required. Refer to Body, Chassis, Electrical Manual, Group 33.
	• Engine.	• Check water pump, block for blockage.
	• Exhaust system.	• Check for restrictions.
Engine fails to reach normal operating temperature	• Open thermostat.	• Test, replace if necessary.
	• Temperature gauge or cold light (False Reading).	• Check electrical circuits and service as required. Refer to electrical section.
	• Low coolant level.	• Fill cooling system, as required.

Figure 35. Troubleshooting Chart

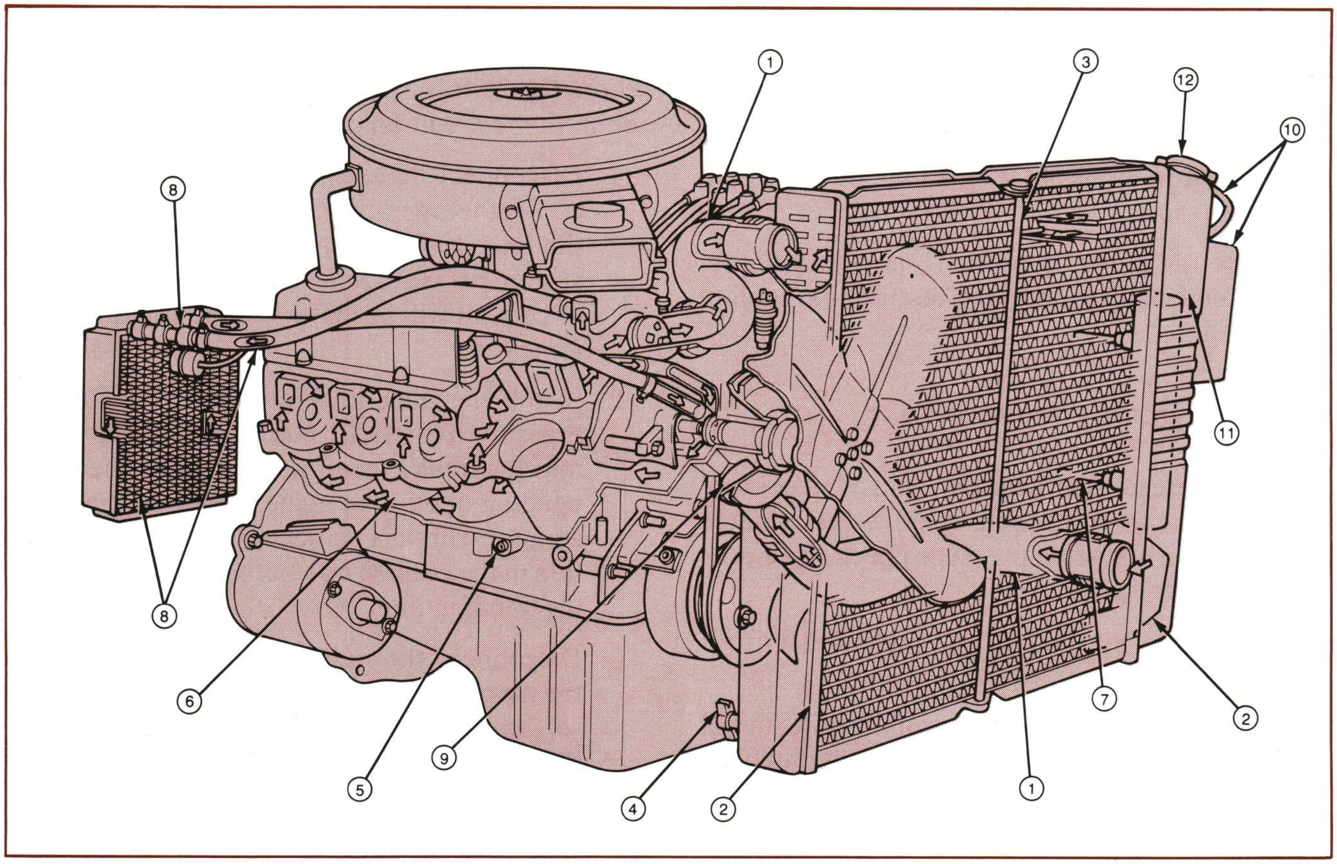


Figure 36. Visual Inspection Points

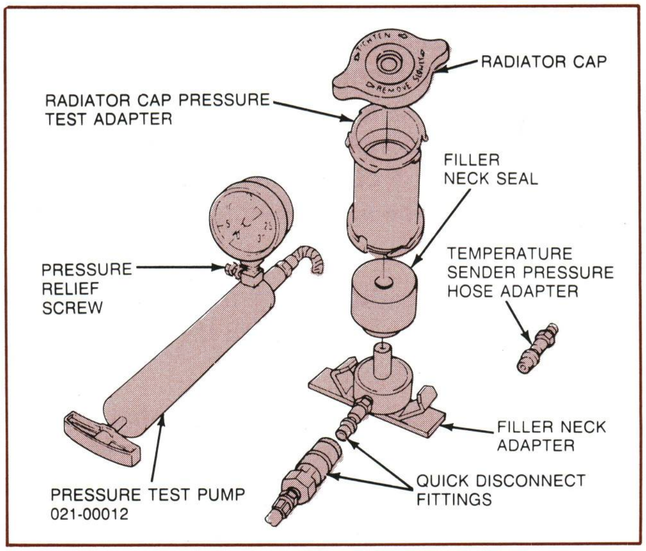

RADIATOR CAP
RADIATOR CAP PRESSURE TEST ADAPTER
FILLER NECK SEAL
PRESSURE RELIEF SCREW
TEMPERATURE SENDER PRESSURE HOSE ADAPTER
FILLER NECK ADAPTER
PRESSURE TEST PUMP 021-00012
QUICK DISCONNECT FITTINGS

Figure 37. Pressure Test Pump and Attachments

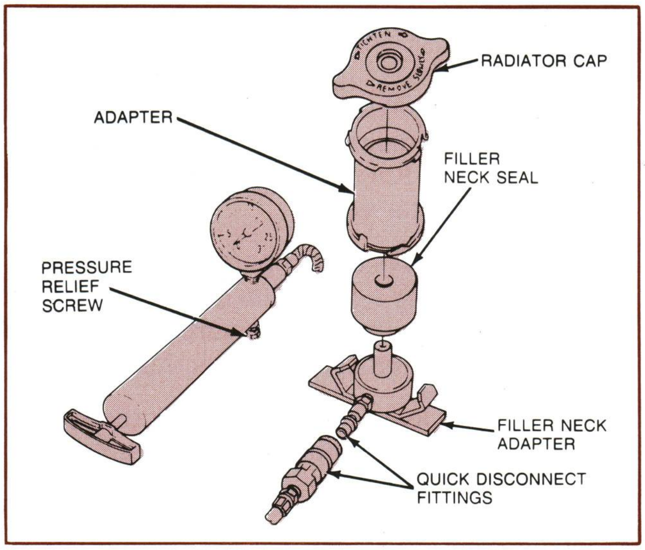


Figure 38. Radiator Cap Pressure Test

8. Tighten the pressure relief screw and repeat Steps 6 and 7 several times to be certain that the test readings are not erratic and are within radiator cap specified pressure limits.
9. If the pressure is not within limits, replace the radiator cap.
10. If the radiator cap pressure is within limits, proceed with a pressure test of the cooling system.

Cooling System Pressure Test

Observing prescribed caution, wait if necessary for the engine to cool; then, remove the radiator cap and begin a system pressure check. The procedure is as follows:

1. Check the coolant level, and adjust it, if necessary.
2. From the parts provided with the Rotunda Tester, Number 021-00012 install the filler neck seal in the radiator filler neck.
3. Insert the filler neck adapter in radiator filler neck, as shown in Figure 39, and rotate it until it locks in place.
4. Connect the hose and pump to the filler neck adapter.
5. Slowly pressurize the system to the lower limit of the radiator cap pressure specified for that system. Excessive pressure could damage the radiator core.
6. Watch the gauge on the pump. It should hold its pressure for a minimum of 2 minutes. If it doesn't, pump the lost pressure back into the system and make a visual inspection for leaks.
7. Correct any leaks found and check the system again to determine that it is holding its pressure.

Combined Radiator Cap and Cooling System Pressure Test

In many cases where a pressure test is to be made, it might be best to test both the cap and the cooling system simultaneously. With this test, the coolant should first be checked and adjusted, as required, to conform with specifications. The radiator cap should be in its fully secured position. When this is done the test can proceed as follows:

1. Disconnect the electrical connector from the coolant temperature sending unit and remove the unit. (With the radiator cap installed and system pressure relieved, only a small amount of coolant will be lost when the sending unit is removed.)
2. Install the filler neck adapter from Rotunda Pressure Tester 021-00012, or its equivalent, into the intake manifold or cylinder head, depending upon the engine being serviced. The adapter will thus be occupying the same position in the coolant circuit that was occupied by the sending unit.
3. Disconnect the radiator overflow hose from the nipple on the filler neck. Attach a length of separate hose of the same inside diameter to the nipple. Be sure that the temporary hose is securely attached at the radiator. Insert the free-end of this hose into a container of water. Refer to Figure 40.
4. Attach the pressure pump and gauge assembly to the adapter fitting and pressurize the system to the radiator cap lower pressure limit. There should be no bubbles in the water with pressure at this lower limit. If there are none, proceed to increase system pressure to the upper limit of cap pressure. At this point, there should be a slight amount of bubbles in the water.
5. Replace the radiator cap if bubbles are not produced in the water when the pressure is at the upper limit.
6. When it is determined that the radiator cap is satisfactory, pressurize the system to specifications and check to see that pressure will hold for approximately two minutes.
7. If the pressure drops within the two minute time span, perform a visual inspection of the system to determine where a leak or leaks are occurring. Fix these leaks and recheck the system to be sure that the pressure will hold for the two minute period.

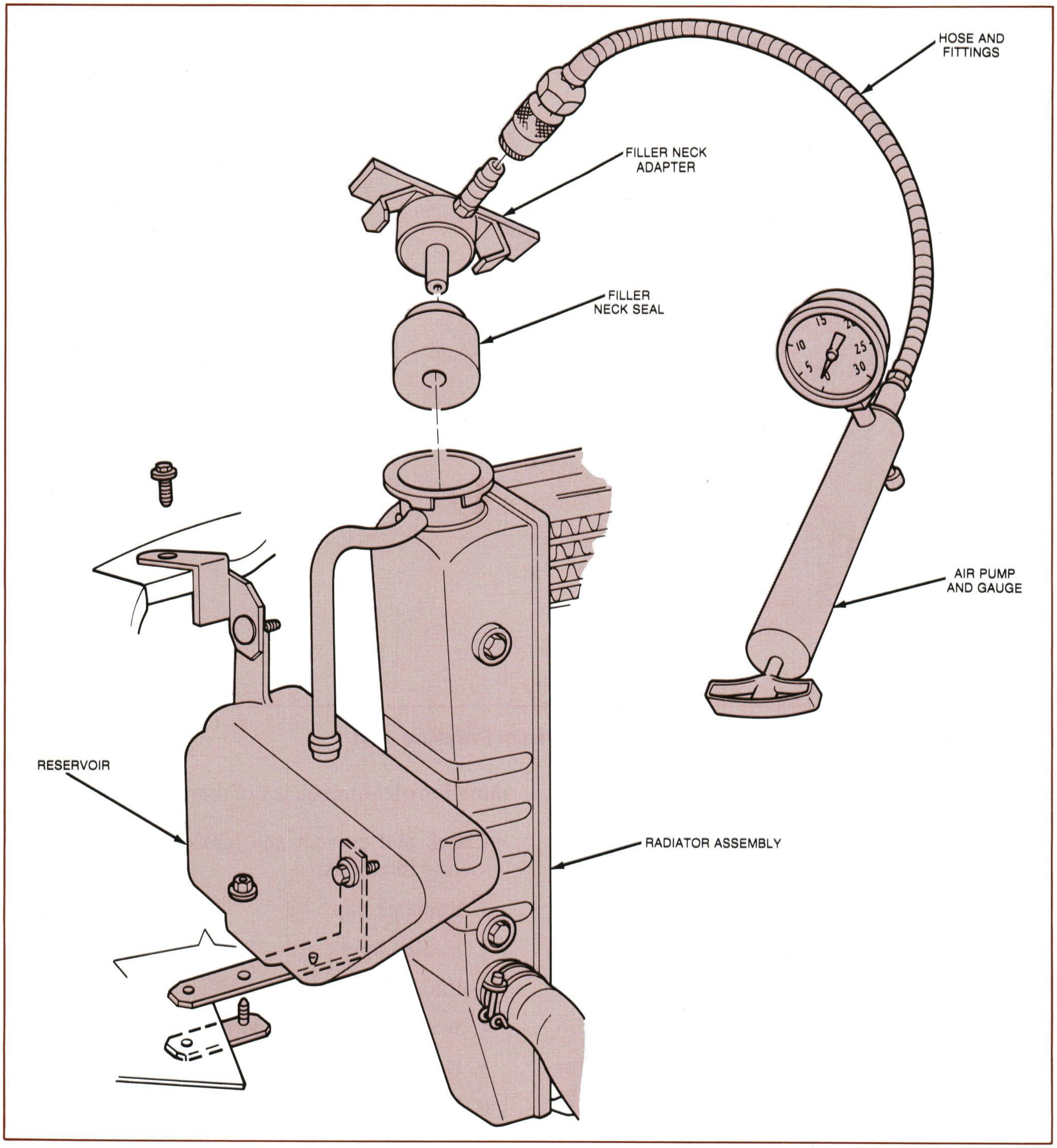


Figure 39. Cooling System Pressure Test

8. Release the system pressure by loosening the radiator cap, remove the test equipment, install the temperature sending unit, check the coolant level and adjust it, as required, with the correct coolant solution.

THERMOSTAT CAUSING OVERHEATING/ UNDERHEATING

If the thermostat is stuck in the closed position, it will not admit coolant to the radiator where it can circulate through the tubes and be cooled. The

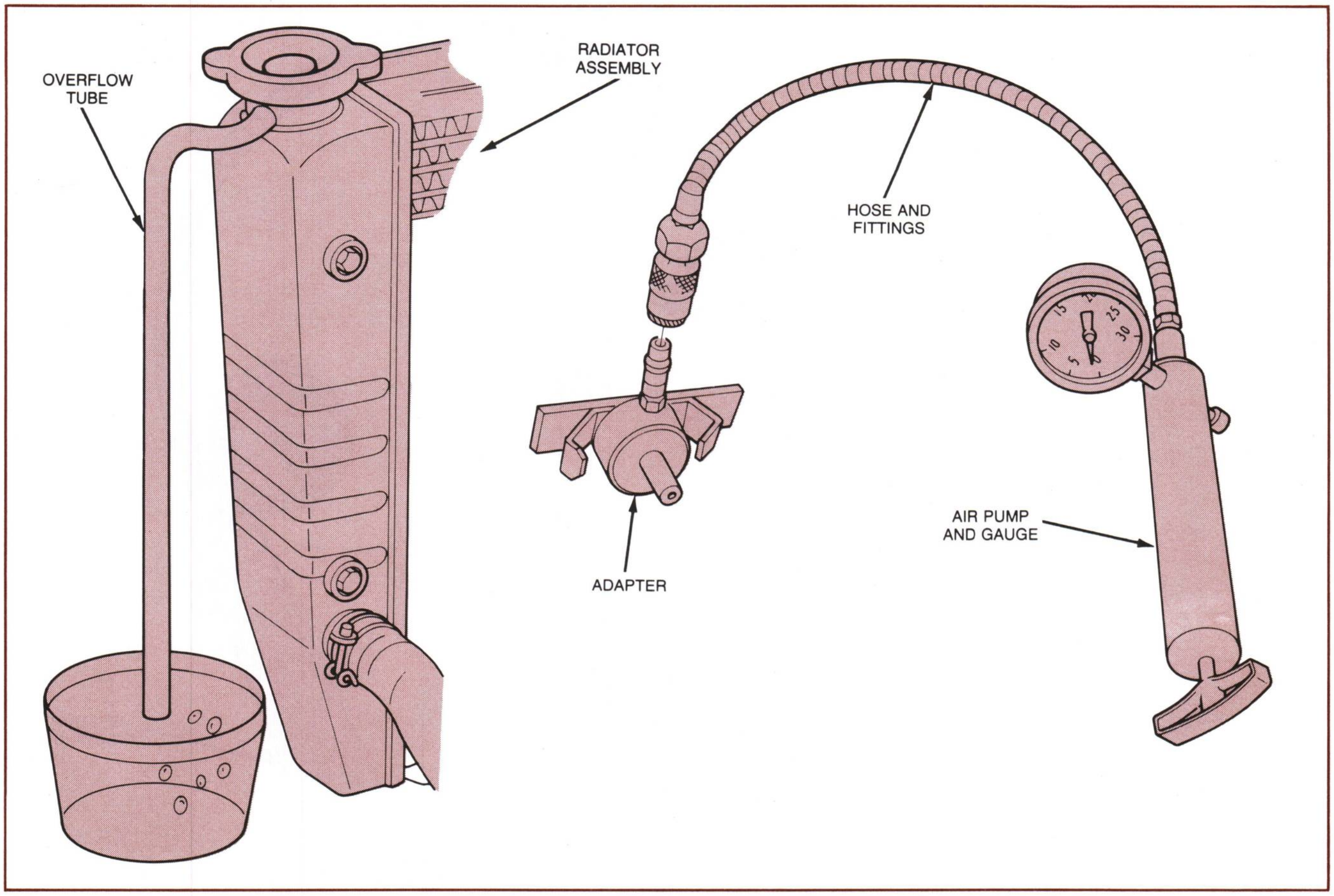


Figure 40. Combined Radiator Cap and Cooling System Pressure Test

coolant flow is directed, instead, through the by-pass circuit for a repeat cycle through the water jackets in the engine. As this cycle continues to repeat, the coolant continues to absorb engine heat without the required interim cooling in the radiator. In this situation, the coolant temperature gauge in the instrument panel will provide a visual warning that the temperature is exceeding safe operating limits.

If the thermostat is stuck in the open position, the coolant will make a continuous circuit through the engine and radiator without allowing sufficient heat absorption during the short period it is in the water jackets. The result is a lack of heat being discharged by the heating system into the passenger compartment through the heater, defroster, and demister outlets.

If either overheating or insufficient heat is a problem, the following procedure will lead to a determination of the adequacy of thermostat operation:

- Check and correct any leaks found in the following locations:
    1. Radiator cap.
    2. Heater hoses.
    3. Radiator hoses.
    4. Water outlet connection gasket.
    5. Head gasket.
    6. Water pump gasket.
- Check the cold engine coolant level and adjust it to specifications. Also, add coolant to the FULL HOT mark on the reservoir.
- With the radiator cap removed, operate the engine to circulate coolant through the system. Continue this operation for approximately 10 minutes. By feel, check to see that coolant is

passing through the radiator and heater core inlet and outlet connections. Circulation may also be observed through the filler neck.

- If during this 10-minute run, the coolant level drops, adjust it by adding coolant until the level settles at the filler neck. Repeat, as required, until the level holds. This indicates that all air has been purged from the system.

- When the 10-minute run has been completed and fluid level adjustments have been made, feel the heater inlet and outlet hoses, as well as the underside of the radiator upper hose. If they are cold and there is evidence of coolant circulation, replace the thermostat.

Although it is not used as frequently as it once was, a bench test can be performed to check thermostat operation. To perform this check immerse the questionable thermostat into a beaker of boiling water (212°F). Refer to Figure 41.

Most engine coolant thermostats are designed to open in a temperature span between 188°F and 195°F. At 212°F, they are fully open. If a thermostat doesn't open 1/4 inch or more when exposed boiling water, it should be replaced. If the problem being encountered is insufficient rather than excessive heat, the thermostat is probably not closing. Holding it in front of a source of light at room temperature should reveal whether the sealing surface is fully closed. If light can be seen around the sealing surface, replace the thermostat.

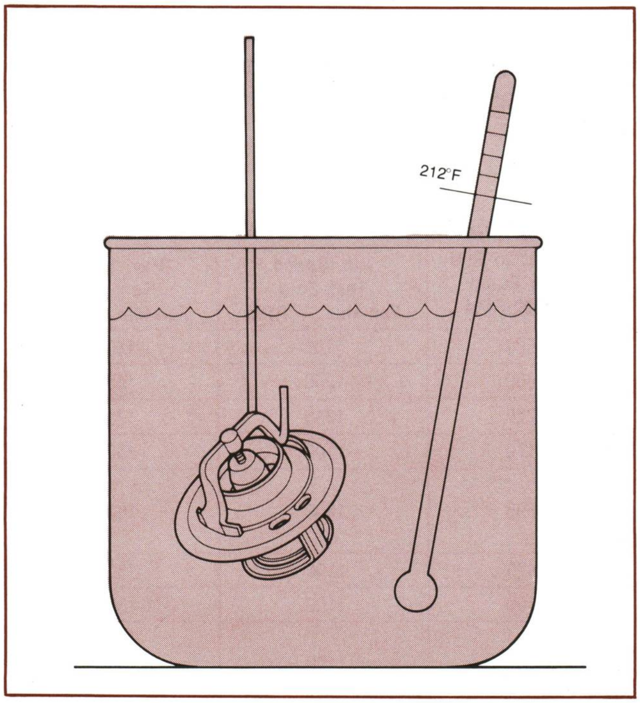


Figure 41. Bench Testing Thermostat Operation

Fan Drive Clutch Test

On vehicles not equipped with a transversely mounted engine, a fan drive clutch and fan are used. If the engine is overheating, even though the thermostat is functioning properly, the clutch may be causing the problem. To test clutch performance, first rotate the fan blade by hand. A slight amount of resistance should be felt. If there is no resistance or there is high resistance, it will be necessary to check the minimum and maximum fan speeds.

Minimum Speed Fan Drive Requirement Test - Cold

The purpose of this test is to determine the amount of slippage occurring between the fan pulley and the fan. The test procedure is as follows:

- Using a suitable marker, mark the water pump pulley hub, one of the fan blade attaching bolts, and the crankshaft pulley. Refer to Figure 42.
- Connect a tachometer to the engine.
- Install a throttle adjusting tool.
- Connect a Sun Strobe Light or equivalent.

  To avoid personal injury or damage to the vehicle, do not operate the engine until the fan has been checked for cracks or separation.

- Start the engine and run it at approximately 1500 rpm until the engine temperature has normalized.
- Adjust the engine rpm to test specifications provided in the shop manual.
- Operate the strobe light with the engine rpm at 2000. Aim it at the water pump pulley. Adjust the engine speed until the light flashes and the water pump pulley synchronize.

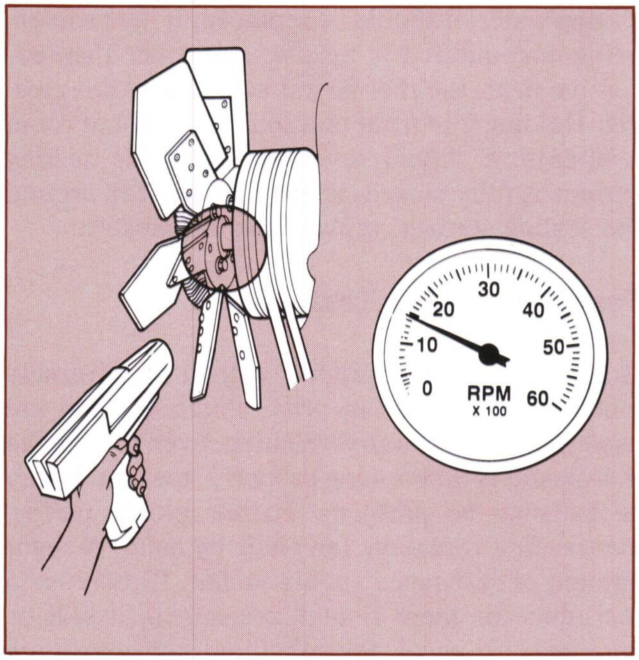


Figure 42. Strobe Light Markings

- Aim the timing light at the fan blade attaching bolts. Synchronize the light flashes with the mark on the bolt.
- The fan speed must not be greater than the specified fan test speed at 2000 water pump rpm. If it is, check for proper parts usage. Replace the fan drive clutch if the correct parts were used. If not, install the correct parts and repeat the test.
- Disconnect the test equipment unless a maximum speed test is to be conducted.

Maximum Speed Fan Drive Requirement Test - Hot

- Perform the first five steps prescribed for the preceding test.
- Block off areas on each side of the radiator core in the engine compartment and the front of the grille. This will raise the temperature of the air striking the clutch control unit and cause the fan to operate at maximum speed.
- Use the strobe light in the same manner as described in preceding test. The fan speed must meet or exceed the specified maximum fan test speed at 2000 water pump rpm. If the fan speed was less than specified, check for correct parts usage. If correct, replace the fan drive clutch; if incorrect, install the right parts and repeat the test.

Figure 43 charts typical fan drive clutch specifications.

- The fan speed must not exceed the specified maximum fan test speed with the water pump rotating at 2000 rpm.
- If the fan speed is less, there may be an incorrect parts application. If so, replace the part(s) and repeat this test. If the parts are correct, replace the fan drive clutch.

FAN DRIVE CLUTCH SPECIFICATIONS

Engine	Vehicle	Cooling Option	Water Pump Pulley Ratio	Engine RPM Required to Run Water Pump @ 2000 RPM	Fan Test Speed Water Pump @ 2000 RPM	
					Min. Speed Test Cold Fan Max. — RPM	Max. Speed Test Hot Fan Min. — RPM
3.8L (232 CID)	Thunderbird/Cougar	Non-A/C, A/C	1.25:1	1600	1100	1600
	Mustang	Non-A/C, A/C	1.25:1	1600	1250	1650
5.0L (302 CID)	Mustang	Non-A/C, A/C	1.13:1	1770	1350	1750
	Thunderbird/Cougar	Non-A/C, A/C	1.36:1	1470	1100	1500
	Ford Crown Victoria/ Mercury Grand Marquis	A/C (Non-A/C)	1.18:1	1695	1200	1600
	Continental/Mark VII	A/C	1.36:1	1470	1100	1500
	Lincoln Town Car	A/C	1.25:1	1600	1100	1500
5.8L HO (351W-CID) Police	Ford Crown Victoria/ Mercury Grand Marquis	Non-A/C, A/C	1.25:1	1600	1100	1500

Figure 43. Typical Fan Drive Clutch Specifications

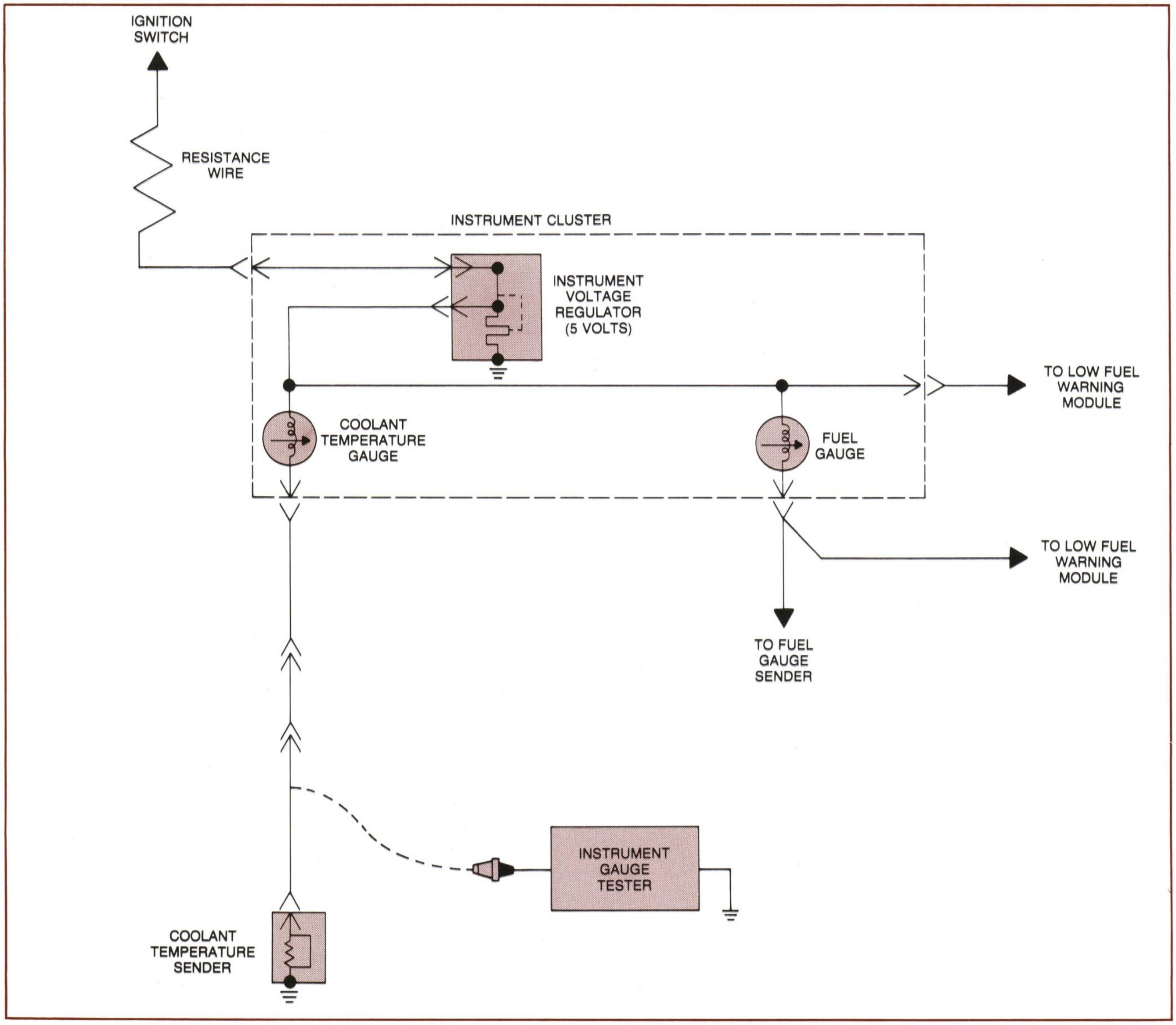

IGNITION SWITCH
RESISTANCE WIRE
INSTRUMENT CLUSTER
INSTRUMENT VOLTAGE REGULATOR (5 VOLTS)
TO LOW FUEL WARNING MODULE
COOLANT TEMPERATURE GAUGE
FUEL GAUGE
TO LOW FUEL WARNING MODULE
TO FUEL GAUGE SENDER
INSTRUMENT GAUGE TESTER
COOLANT TEMPERATURE SENDER

Figure 44. Instrument Voltage Regulator and Coolant Temperature Gauge

INOPERATIVE/INACCURATE COOLANT TEMPERATURE GAUGE

An instrument voltage regulator located in the instrument cluster supplies a pulsating output voltage to power the coolant temperature gauge and the fuel gauge. The output of this regulator is 5.0 volts. The coolant temperature gauge is connected to the coolant temperature sender which is a temperature sensitive variable resistor. When the coolant temperature is low, the resistance is high; when the temperature is high the resistance is low.

Figure 22 is repeated as Figure 44 to illustrate a typical circuit in which the regulator and gauges are contained.

The coolant temperature gauge and the fuel gauge are tied together through the instrument voltage regulator as Figure 44 shows. Thus, if there is erratic action or incorrectly high or low gauge readings, both gauges may be similarly affected. In any case, there are some checks to be made:

- The engine-to-body ground for a clean, tight

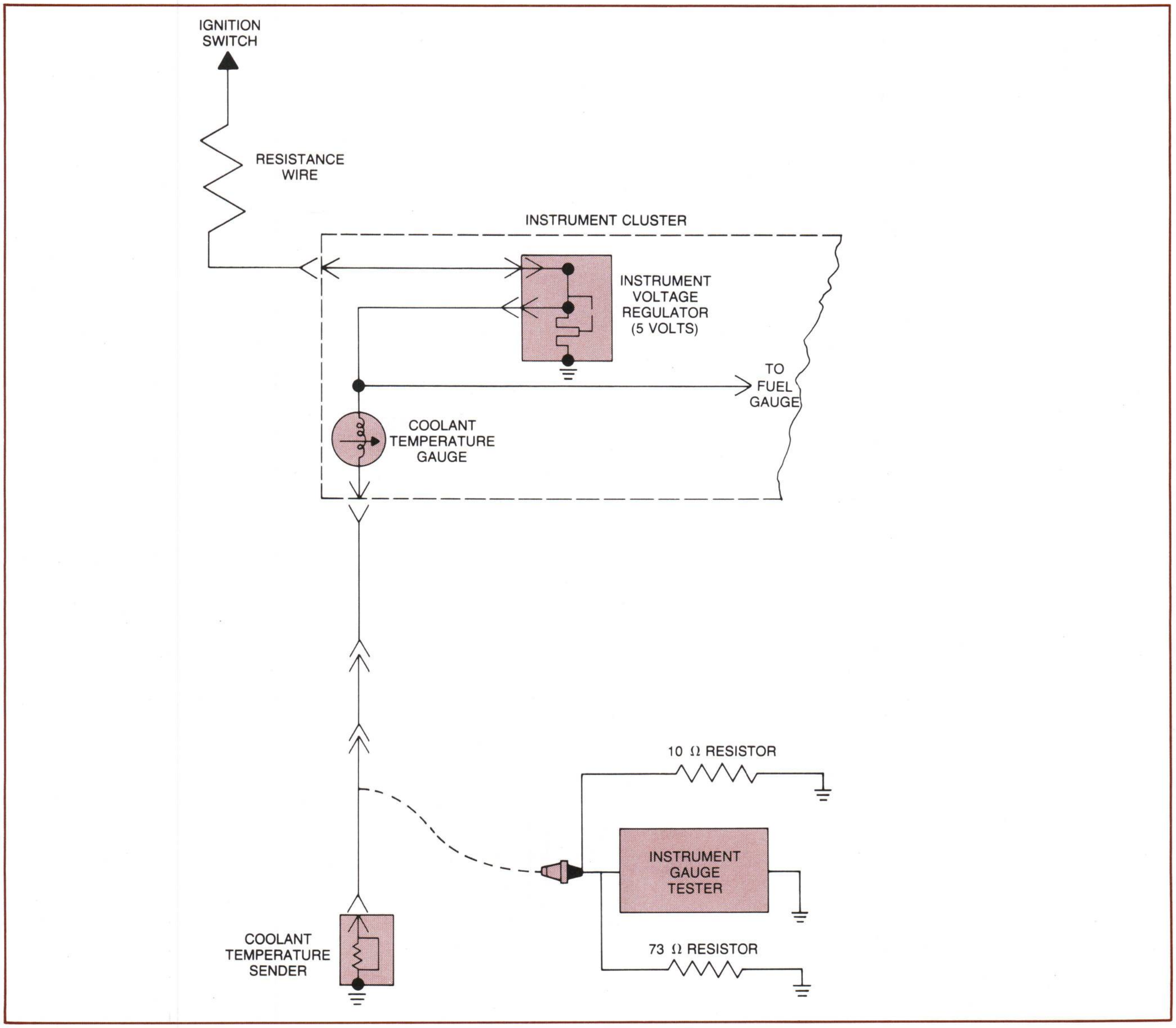


Figure 45. Gauge Calibration Check

connection.

- The instrument voltage regulator ground. (As shown in Figure 44, the IVR is grounded through its case.)
- Check for voltage in the lead between the instrument cluster and the solid state module which connects to the IVR output circuit to the coolant and fuel gauges.
- If the preceding checks indicate circuit difficulty, bench test the regulator.

CAUTION: Do not ground either terminal in the instrument voltage regulator. Do not check resistance across the coolant temperature sender.

If the coolant temperature gauge or both gauges appear to be out of calibration, verify the condition with the following procedure:

- Refer to Figure 45.
- Disconnect the wire leading from the coolant temperature sender.

- Connect a test light between the gauge lead and ground. If the light stays on or blinks erratically, replace the regulator. If the test light doesn't light, check for an open circuit in the gauge or wiring. (Normal gauge resistance is 10 to 14 ohms.)
- Check the gauge calibration with a 10 ohm and a 73 ohm resistor as shown in Figure 45. With the ignition switch on, the resistances should produce high and low readings, respectively.
- If the gauge tests within calibration, replace the sender; if it tests out of calibration, replace the gauge.

ELECTRO-DRIVE COOLING FAN

For review, we'll highlight some of the general information provided previously about the electro-drive cooling fan and the cooling fan controller. As a preface to this review, let us emphasize that the electro-drive fan will be accompanied with a temperature control switch in its circuit as a singular means of control or it will have both a temperature control switch and a cooling fan controller.

The cooling fan in the larger rear wheel drive vehicles will be powered by a temperature sensitive fan drive clutch. On smaller vehicles with front wheel drive, as well as certain rear wheel drive vehicles which require extra cooling, the fan will be driven by an electric motor. Control of electro-drive fan operation, whether it is by temperature control switch alone or in combination with a fan controller, will depend upon the engine and accessories involved. The shop manual should be consulted for complete application data.

In a vehicle equipped with an electro-drive cooling fan and air conditioning, the fan will be controlled by the cooling fan controller. The fan motor will be energized when the A/C clutch cycling pressure switch closes while the A/C function selector lever or knob is in an A/C position, mix position, or defrost position. Going a step further, the A/C clutch coil which engages with the A/C compressor driveshaft will be energized by voltage at the fan motor. The clutch will continue to cycle in rhythm with the clutch cycling pressure switch.

It may be helpful to better understand this circuit between the clutch cycling pressure switch and the fan if it is illustrated.

Figure 46 shows the switch and the suction accumulator/drier from which it receives the suction pressure for control switch operation.

Remember the coolant temperature switch operates independently of the compressor drive cir-

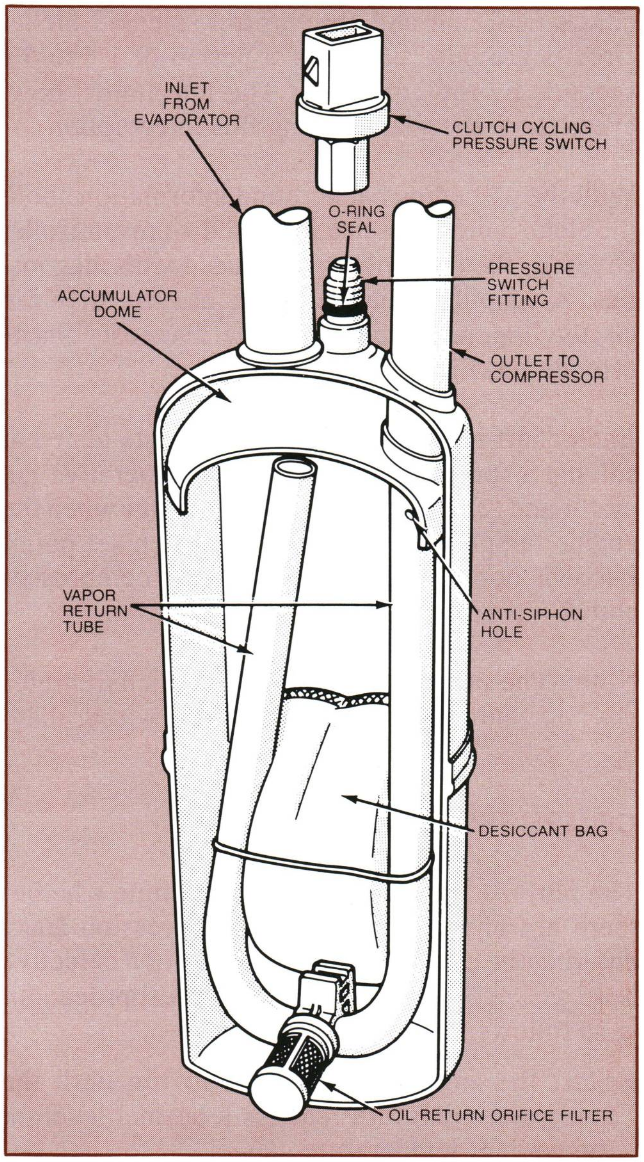


Figure 46. A/C Compressor Clutch Cycling Pressure Switch

cuit. It will close when the temperature reaches 221°F and complete a circuit through the cooling fan controller directly to the cooling fan motor.

The cooling fan controller is involved with several other circuits which affect cooling fan operation. One is the wide-open-throttle (WOT) cutout switch used in some A/C applications. During hard acceleration, this cutout switch signals the controller to cut power to the compressor clutch field coil and a throttle kicker solenoid. Another circuit indirectly affecting the fan is the stop lamp switch. When the power brakes are applied, the A/C clutch field coil and the throttle solenoid kicker circuits are interrupted for a period of 1.5 to 5.0 seconds by the controller. The fan motor, however, stays energized during this interruption.

With the preceding background information about the electro-drive cooling fan and the fan controller covered, the text will now proceed with diagnostics. A simplified diagram of an electro-drive fan circuit, Figure 47, precedes the diagnosis charts provided in Figures 48 and 49.

Each chart includes a sequence of tests aimed at solving a specific problem: (1) an inoperative fan motor and (2) a fan motor which operates when the engine temperature reaches the switch set point, but will not operate when the A/C compressor clutch is engaged.

Note: The numbers called out in the charts refer to numbers appearing in the wiring diagram.

COMPRESSION LEAK TEST

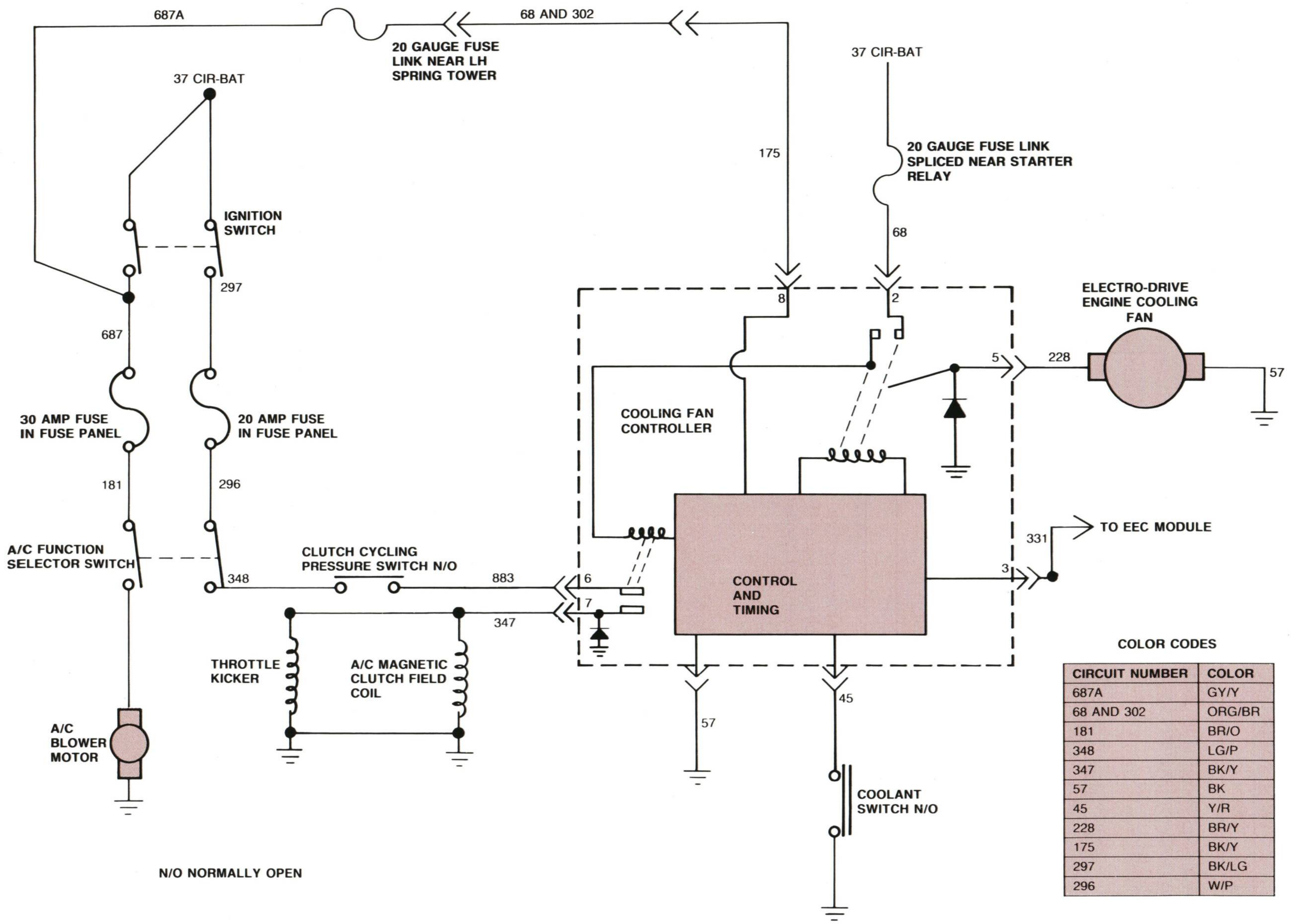
The purpose for this test is to determine whether there are any combustion or compression leaks entering the cooling system because of a defective head gasket or a casting crack. The test procedure is as follows:

- Start the engine and allow it to run until the coolant temperature reaches a normal level on the coolant temperature gauge.
- With the engine continuing to run, carefully remove the radiator pressure cap.
- Using pressure test pump and attachment tool set, 021-00012, insert the filler neck seal into the filler neck; then, insert the filler neck adapter into the filler neck and lock it into position. See Figure 50.
- Connect the hose, gauge, and pump to the filler neck adapter.
- If, without operating the pump, the gauge shows an immediate pressure build-up, there may be a compression leak into the cooling system.
- If there is no sudden rise in pressure, operate the pump being very careful not to exceed the pressure limit of the radiator cap. If the gauge needle vibrates, a compression or combustion leak into the cooling system is indicated.
- Isolate the leak by shorting each spark plug in sequence. Gauge needle vibrations should diminish or stop completely when the spark plug for the leaking cylinder is shorted.
- After the leak has been serviced and repaired, repeat the preceding step to be sure that the leak no longer exists.

DELAY VALVES WHICH MIGHT AFFECT COOLING SYSTEM EFFICIENCY

There are a number of delay valves which must operate within their individually specified minimum and maximum delay periods if their affect on cooling system efficiency is to be satisfactory. (The delay interval is expressed in seconds.) Among the valves involved are: (1) the spark delay valve, (2) the retard delay valve, (3) the air cleaner delay valve, and (4) the distributor vacuum vent valve.

If one or more of these valves should be operating outside its specified delay limits, the cooling system may be adversely affected. Tests to determine their suitability are covered in detail in the shop manual.


687A
68 AND 302
20 GAUGE FUSE LINK NEAR LH SPRING TOWER
37 CIR-BAT
37 CIR-BAT
175
20 GAUGE FUSE LINK SPLICED NEAR STARTER RELAY
68
IGNITION SWITCH
297
687
8
2
ELECTRO-DRIVE ENGINE COOLING FAN
5
228
57
30 AMP FUSE IN FUSE PANEL
20 AMP FUSE IN FUSE PANEL
COOLING FAN CONTROLLER
181
296
TO EEC MODULE
331
A/C FUNCTION SELECTOR SWITCH
348
CLUTCH CYCLING PRESSURE SWITCH N/O
883
6
7
3
CONTROL AND TIMING
347
THROTTLE KICKER
A/C MAGNETIC CLUTCH FIELD COIL
57
45
A/C BLOWER MOTOR
COOLANT SWITCH N/O
N/O NORMALLY OPEN

COLOR CODES

CIRCUIT NUMBER	COLOR
687A	GY/Y
68 AND 302	ORG/BR
181	BR/O
348	LG/P
347	BK/Y
57	BK
45	Y/R
228	BR/Y
175	BK/Y
297	BK/LG
296	W/P

Figure 47. Electro-drive Cooling System Wiring Diagram

FAN MOTOR INOPERATIVE

TEST	RESULT ▶	ACTION TO TAKE
TEST 1		
• Disconnect motor lead. Jumper neg. to ground and pos. to B+ at motor.	Motor does not run ▶	REPLACE motor.
	Motor runs ▶	CONNECT motor lead and GO to **Test 2**.
TEST 2		
• Unplug connector at coolant temperature switch. Jumper from connector to ground on circuit 45. Turn ignition switch to Run.	Motor runs ▶	CHECK switch ground. If ground is OK, REPLACE coolant temperature switch.
	Motor does not run ▶	GO to **Test 3**.
TEST 3		
• Turn ignition switch to OFF and remove jumper installed in Step 2. Check continuity of circuit 45 from cooling fan controller (Terminal 1) to coolant temp. switch.	Continuity ~~OK~~ ▶	CHECK circuit 45 for an open.
	Continuity OK ▶	JUMPER coolant temperature switch wire to ground and GO to **Test 4**.
TEST 4		
• Jumper from B+ to circuit 687 at cooling fan controller (Terminal 8). Do not disconnect wiring connector from controller.	Motor runs ▶	CHECK ignition feed circuits 68 and 687 for an open.
	Motor does not run ▶	REMOVE jumper and GO to Test 5.
TEST 5		
• Disconnect the wiring connector at the cooling fan controller. Jumper B+ to circuit 228 (Terminal 5).	Motor does not run ▶	CHECK circuit 228 for an open.
	Motor runs ▶	REMOVE jumper and GO to **Test 6**.
TEST 6		
• Connect a jumper from circuit 68 to 228 (Terminals 2 & 5) at the cooling fan controller connector.	Motor does not run ▶	CHECK circuit 68 for an open.
	Motor runs ▶	REPLACE cooling fan controller and REMOVE jumper from temp. switch wire.

Figure 48. Inoperative Fan Motor Tests

FAN MOTOR OPERATES WHEN ENGINE TEMPERATURE REACHES SWITCH SET POINT BUT DOES NOT OPERATE IN THE A/C MODE

TEST	RESULT ▶	ACTION TO TAKE
TEST 1 • Place A/C function selector switch in an A/C or DEFROST position.	Fan motor does not engage ▶	GO to Test **2**.
	Fan motor engages ▶	GO to Test **9**.
TEST 2 • Check 20 amp fuse in fuse panel.	Blown ▶	REPLACE.
	Good fuse ▶	GO to Test **3**.
TEST 3 • Disconnect A/C clutch cycle pressure switch. Jump across connector.	Fan motor engages ▶	GO to Test **4**.
	Fan motor does not engage ▶	GO to Test **7**.
TEST 4 • Check A/C system for loss of refrigerant charge.	No refrigerant charge ▶	Leak test, SERVICE and CHARGE system.
	Refrigerant system has charge with low pressure above 50 psi ▶	GO to Test **5**.
TEST 5 • Check wide open throttle signal from EEC.	Ground ▶	SERVICE linkage or EEC signal.
	Voltage ▶	GO to Test **6**.
TEST 6 • Check for continuity across the A/C clutch cycling pressure switch. Remove switch connector.	No continuity ▶	REPLACE the A/C clutch cycling pressure switch
	Continuity ▶	GO to Test **9**.
TEST 7 • Check for voltage on 348 Circuit at A/C clutch cycling pressure switch.	Voltage OK ▶	GO to Test **9**.
	No voltage ▶	GO to Test **8**.
TEST 8 • Check for voltage on 296 and 348 Circuits at function selector switch in instrument panel.	Voltage on 296 but not on 348 ▶	SERVICE A/C control assembly.
	No voltage on 296 circuit ▶	TRACE Circuits 296 and 297 toward ignition switch.

Figure 49. Fan Motor Operates When Engine Temperature Reaches Switch Set Point, But Does Not Operate With A/C Compressor Clutch Engaged

FAN MOTOR OPERATES WHEN ENGINE TEMPERATURE REACHES SWITCH SET POINT BUT DOES NOT OPERATE IN THE A/C MODE — Continued

TEST	RESULT ▶	ACTION TO TAKE
TEST 9		
• Check for voltage on 883 Circuit at Pin 6 of cooling fan controller.	Voltage (OK) ▶	GO to Test **10**.
	No voltage ▶	SERVICE open 883 circuit to controller.
TEST 10		
• Ground 57 Circuit at Pin 4 of controller — controller must be connected.	Electro-drive fan runs ▶	SERVICE ground circuit.
	Electro-drive fan does not run ▶	REPLACE controller.

Figure 49. Fan Motor Operates When Engine Temperature Reaches Switch Set Point, But Does Not Operate With A/C Compressor Clutch Engaged

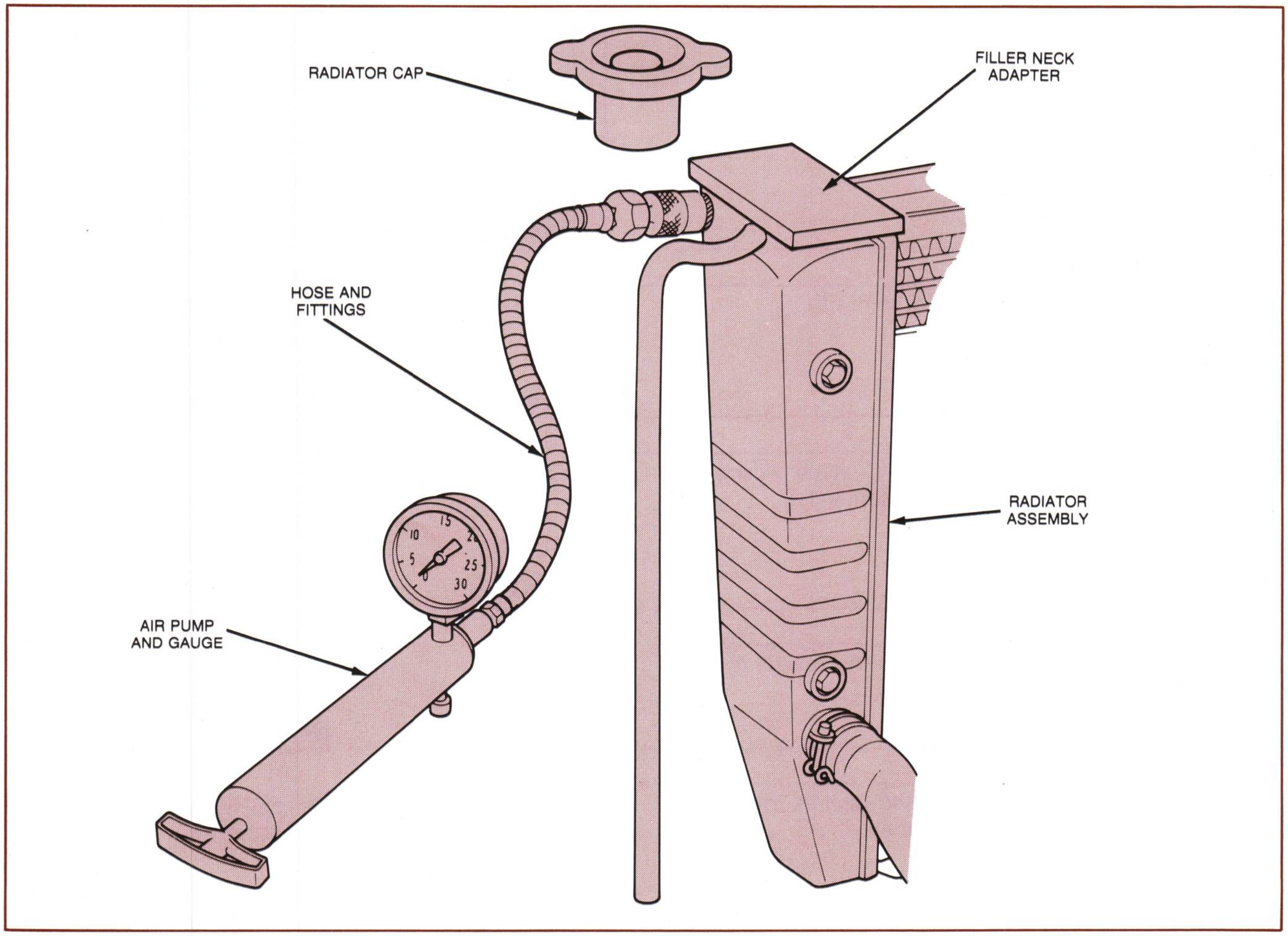


Figure 50. Compression Leak Test

THE DANGERS IN INADEQUATE COOLANT TEMPERATURE CONTROL

Operating the vehicle's engine when coolant temperatures are too high or too low can seriously affect engine performance and shorten the service life expected from component parts. For example:

- An engine that is allowed to operate while it is overheated -
    1. Can end up with burned valves, scored pistons, and damaged bearings.
    2. Can elevate lubricating oil temperatures to the point where the affect of viscosity and detergent action is significantly changed.
    3. Can, because the oil temperature is too high, cause varnish to deposit and accumulate on metal parts. If the accumulation is heavy enough, parts with close tolerance fits could bind or operate under an undesirable state of friction.
- An engine that is allowed to operate beyond its normal warm-up period without reaching an operating temperature of 195°F -
    1. Can cause incomplete fuel vaporization, excessive fuel consumption, excessive emission pollutants, and a generally poor engine performance.
    2. Can dilute the engine oil by causing water vapor to accumulate in the crankcase.
    3. Can accelerate cylinder wall wear. (It has been determined that an engine operating with a coolant temperature of 100°F will increase the rate of cylinder wall wear eight times over the rate of wear if the coolant temperature was 195°F).

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